# MONALISA on Apple

## monitoring key environmental parameters of the alpine environment:

## the apple quality in the focus of science and technology

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unibz

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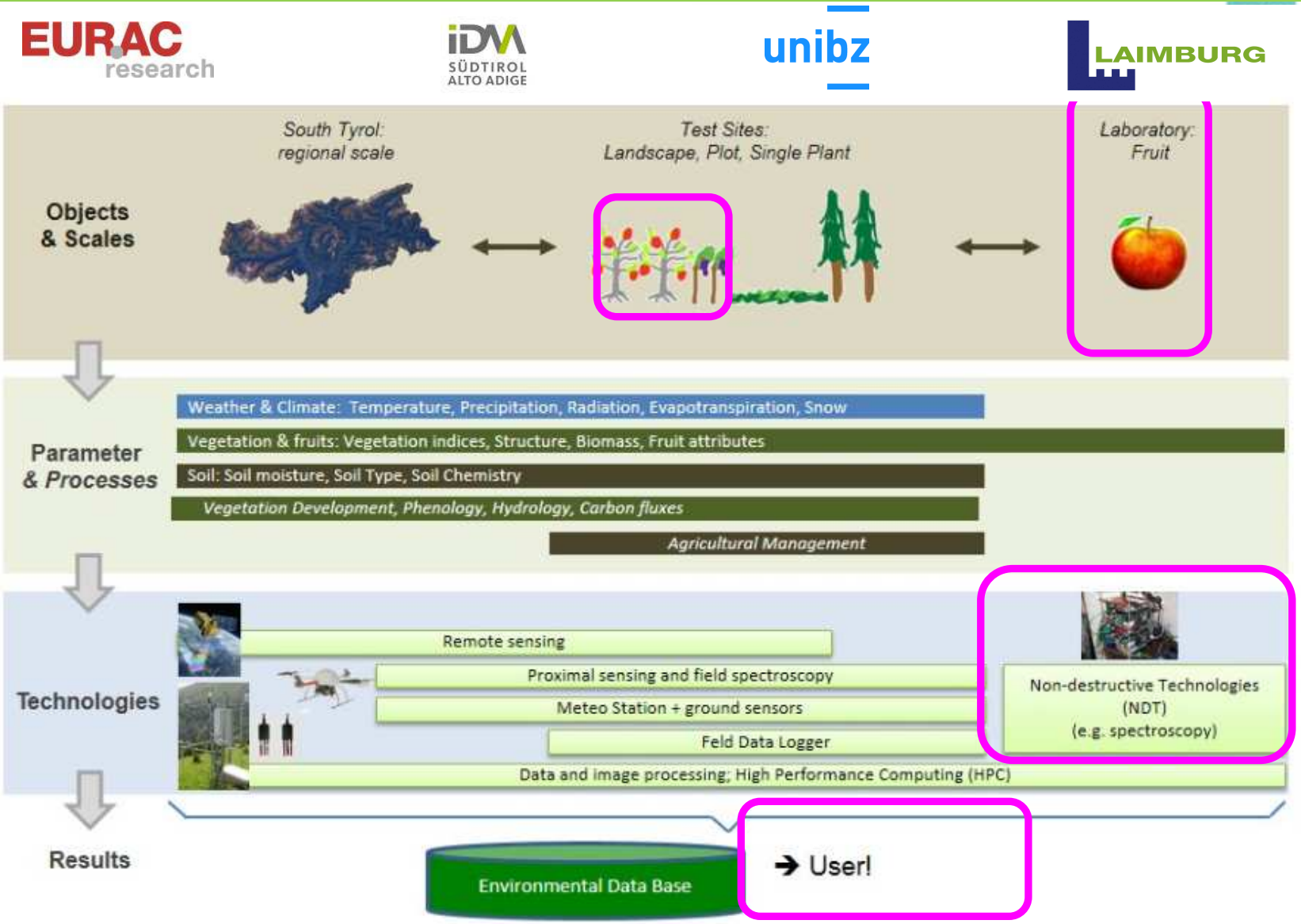
MONALISA

# The multi-scale project MONALISA

- time span: 3 years (2013 - 2016)
- funded by the Autonomous Province of Bolzano
- Collaborating partners:
  the main South Tyrolean research organizations

# Monitoring key environmental parameters in the Alpine Environment involving science, technology and application



# The Apple Ecosystem

**Eddy covariance** is one of the most reliable methodology to **assess water and carbon fluxes** at ecosystem level

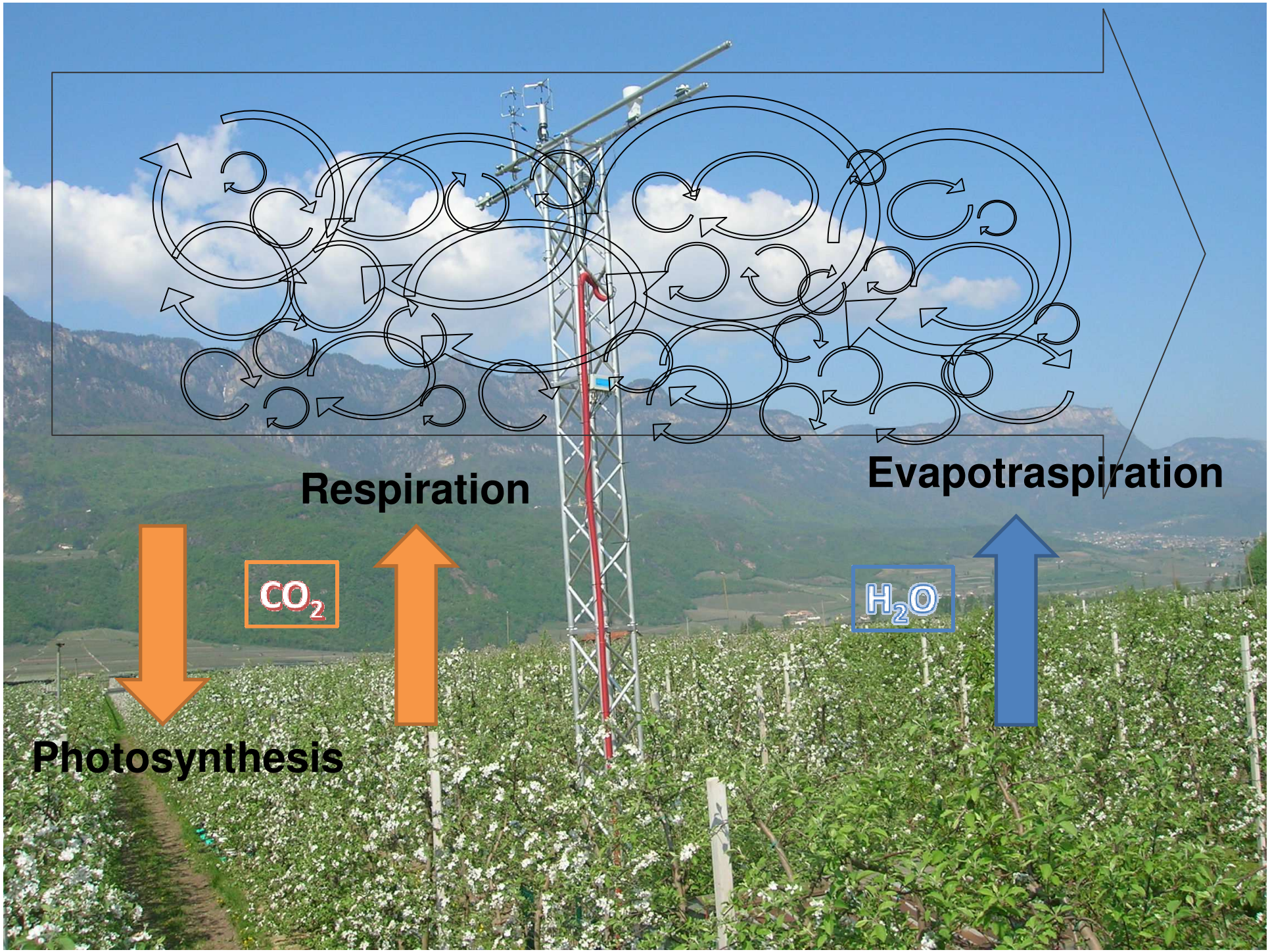
- Sustainable production systems should
  - minimize their C emissions to the atmosphere
  - or even become a sink

- A precise prediction of crop water requirements to maximize the efficiency of irrigation

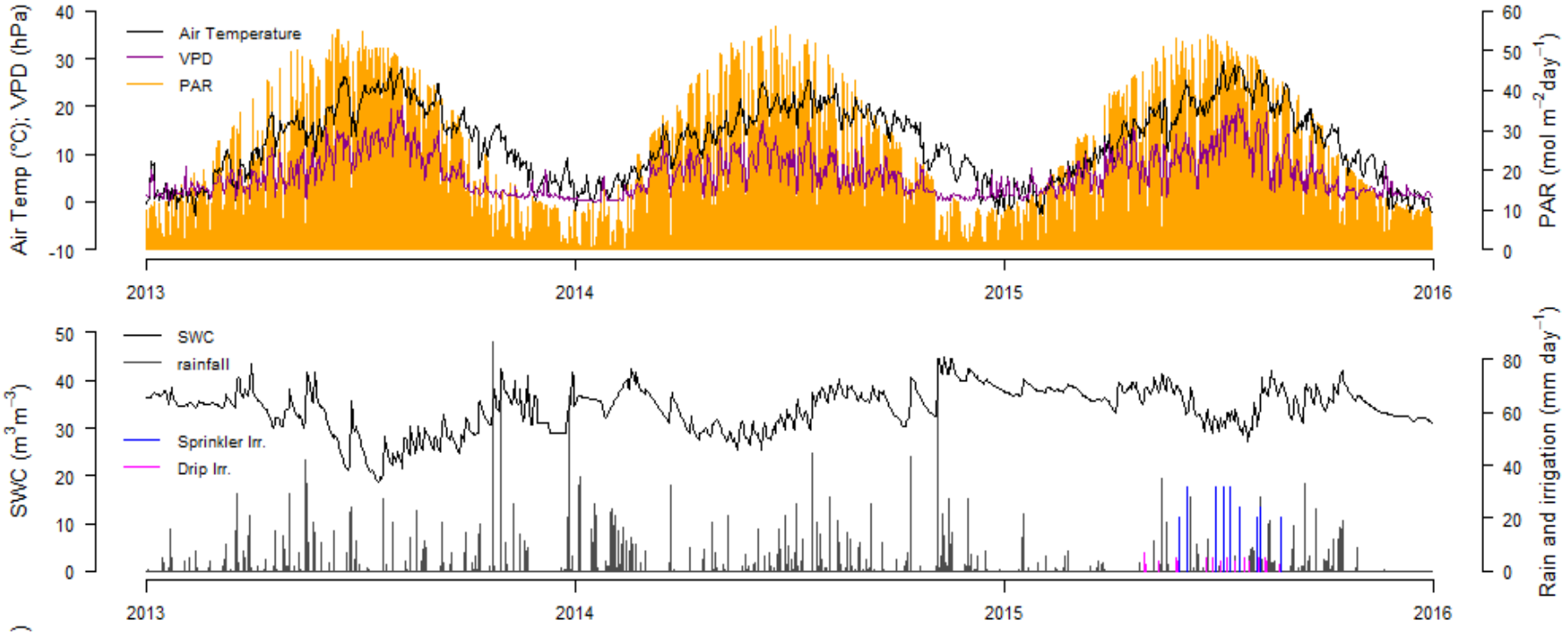
# WP3.1 - Monitoring carbon and water fluxes

## between soil/vegetation and the atmosphere in intensive apple orchards

- **Eddy covariance $CO_2$ and $H_2O$ flux data**
  - 8m tower (4 m above canopy)
  - IRGA (LI-7200)
  - 3D sonic anemometer (Gill R3-50)
- **Meteorological data**
  - Net radiation (CNR1 K&Z)
  - Soil Water content (CS 616-L)
  - Air temperature and RH (CS-215)
  - Precipitation (Rain-o-matic)
  - PAR (SKP215)
- **Other instruments**
  - NDVI and PRI sensors
  - Phenocamera


Respiration
Evapotraspiration
$CO_2$
$H_2O$
Photosynthesis

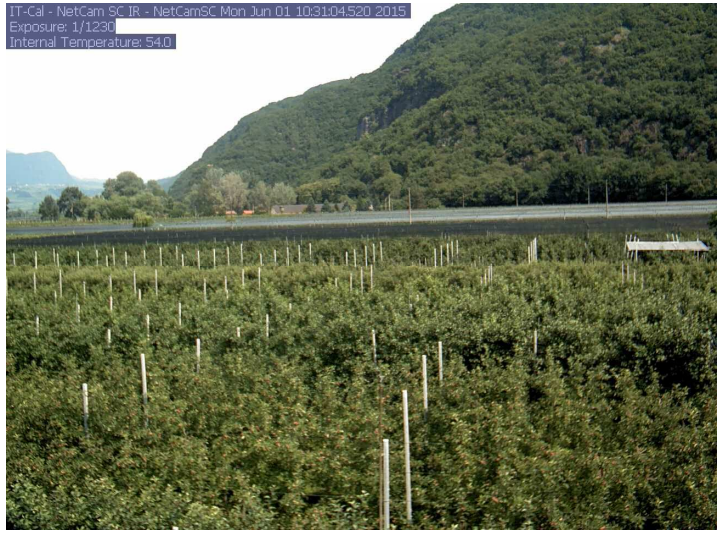
# Environmental drivers 2013 -2015




| Environmental parameters | 2013 | 2014 | 2015 |
|---|---|---|---|
| cum. Rain (mm $y^{-1}$) | 1113 | 1277 | 573 |
| cum. PAR (mol $m^{-2}$ $y^{-1}$) | 8813 | 8546 | 9034 |
| av. Tair (°C) | 12.4 | 12.8 | 12.5 |
| av. VPD (hPa) | 5.8 | 5.1 | 6.3 |

# Phenology

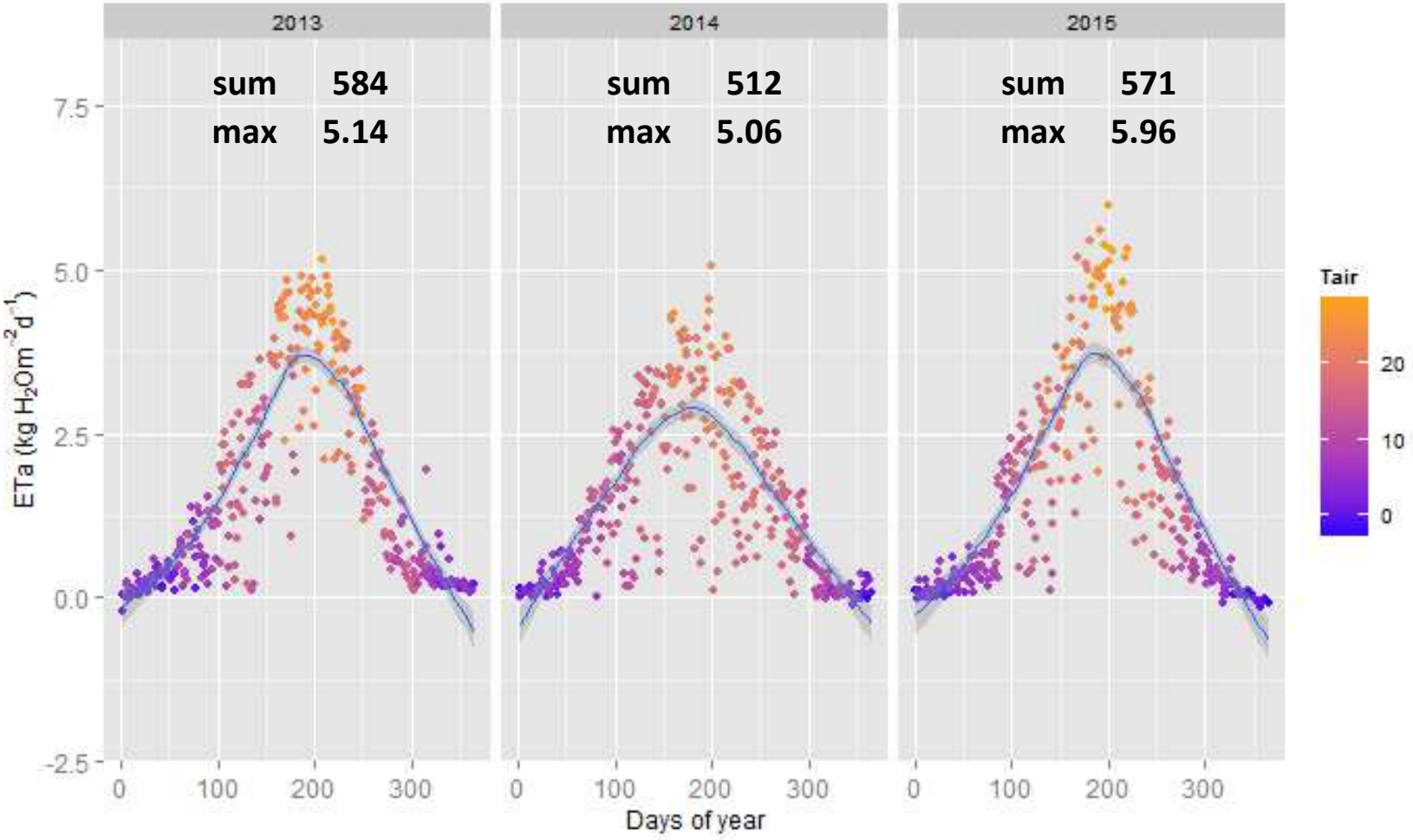

IT-Cal - NetCam SC IR - NetCamSC Wed Apr 15 10:31:04.415 2015
Exposure: 1/2526
Internal Temperature: 48.0


IT-Cal - NetCam SC IR - NetCamSC Mon Jun 01 10:31:04.520 2015
Exposure: 1/1230
Internal Temperature: 54.0


IT-Cal - NetCam SC IR - NetCamSC Tue Sep 01 10:31:04.418 2015
Exposure: 1/1170
Internal Temperature: 54.0

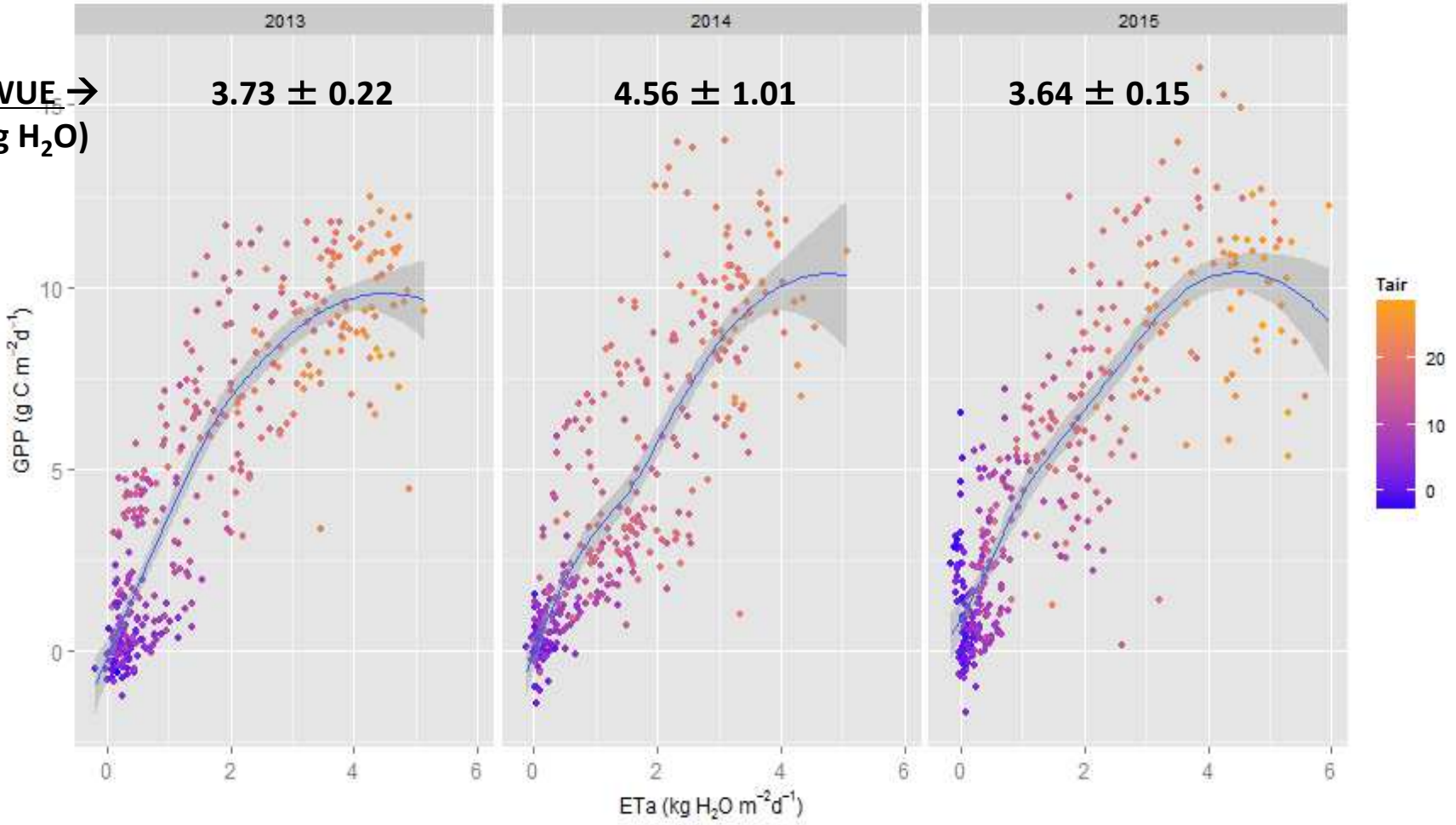

IT-Cal - NetCam SC IR - NetCamSC Mon Nov 30 10:31:03.716 2015
Exposure: 1/1777
Internal Temperature: 29.5

# Water consumption (ETa 2013-15, mm)



# Gross Photosynthesis (GPP) vs ETa

**Mean WUE →**
**(g C / kg $H_2O$)**



# Eddy covariance proved to be very efficient

- To assess either carbon or water fluxes at ecosystem scale.
- Three years of data are available at half hourly and daily time scale.
- ***Apple orchard confirmed its potential to store Carbon in soil and woody structure over multiple years*** *(Zanotelli et al., 2015, Europ. J. Agronomy)*
- Preliminary data analysis showed that WUE decreases at high temperatures and it is higher in years with higher precipitation and average relative humidity.

# Apple Crop Monitoring and Operational Monitoring

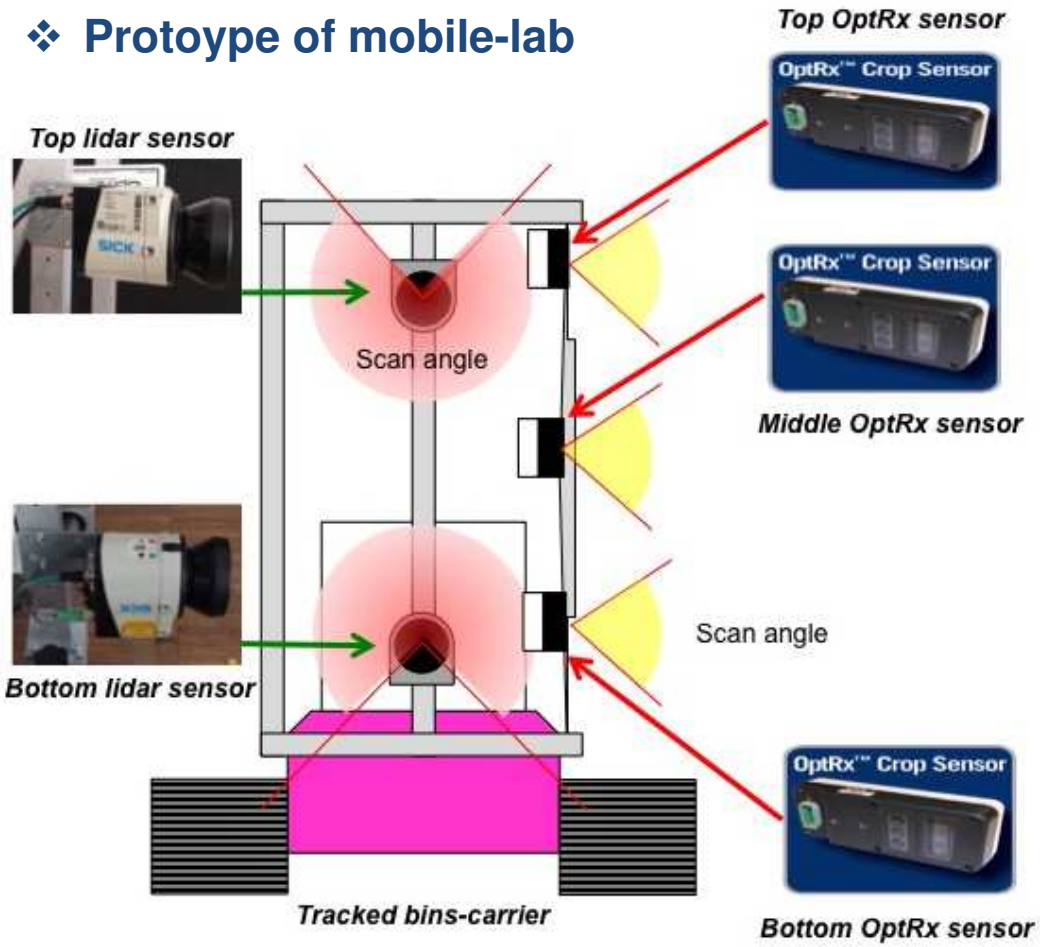
- **AIM:** Need of **improving** ***farm management activities*** integrating **technical**, **environmental** and **profitable** approaches
- Developing an ***integrated framework***
  - for **monitoring key environmental parameters** at a **plot** (and **sub-plot**) scale
  - relevant to the *needs* and *standpoints* of ***private enterprises***
  - ❖ Focus on farming and forest systems (*intensive and extensive)*
  - ❖ Profitability, sustainability and quality of products (→ *certification*)
  - ❖ Application of *Precision Farming* approaches
  - ❖ Monitoring activities concerning not only the environmental components but also the *means of production* (land processes and machines)

# Crop Monitoring

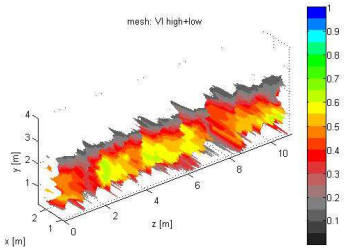
- ***Crop Monitoring*** : monitoring the **vigor** and the **state of the canopy** in intensive orchards
- **Mobile ground sensing optical sensors (GSOS)**
  - *periodical* ***non–destructive***, ***in-motion*** measures
  - in proximity of the canopy (high representativity)
- GSOS ***overcome*** the general problems of conventional remote sensing (RS) techniques
- GSOS provide a ***near side-view*** of the canopy, with more accurate details

# Crop Monitoring: Methodology

❖ **Protoype of mobile-lab**



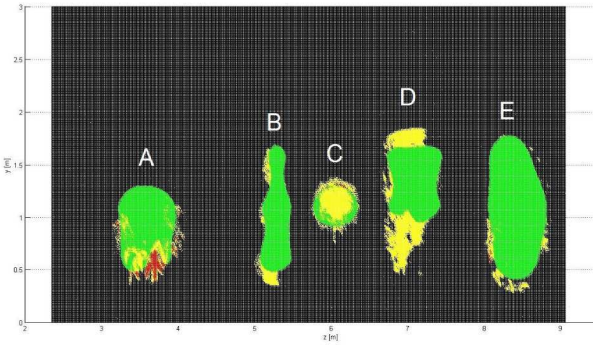

❖ **Laboratory tests** *(calibration and effects of vibrations)*

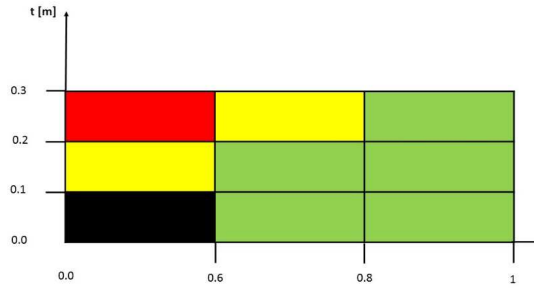




❖ **Field tests** *(combining LIDAR and NDVI measures at plot scale)*

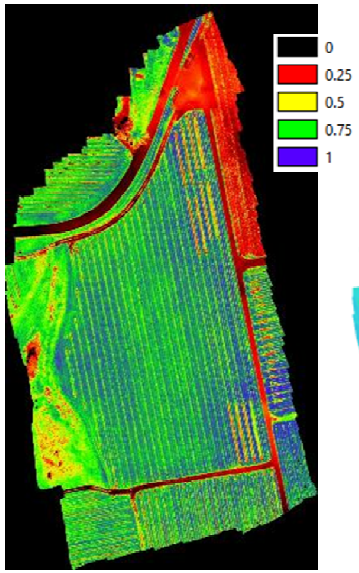
# Crop Monitoring: Results

- Capability of **disease early detection** (combining LIDAR & NDVI measures)
- Detection with **high details** that could be even useful for site-speficic automation approaches
- **Good correlations with top-view surveys** carried out by UAVs, carried out with *fewer work times*
- **Good correlations with bloom charge** and final yields (useful **for planning thinning and harvesting operations**)

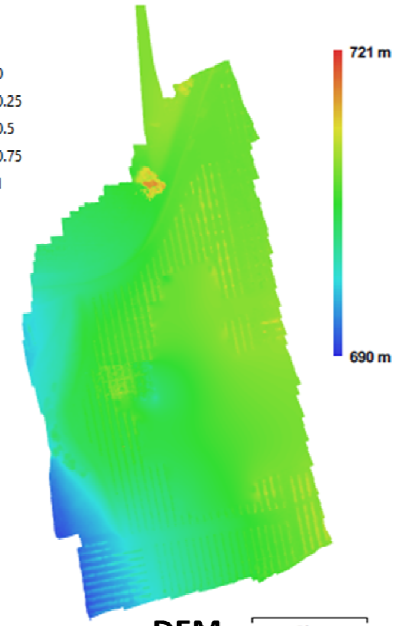



RGB




NDVI




DEM

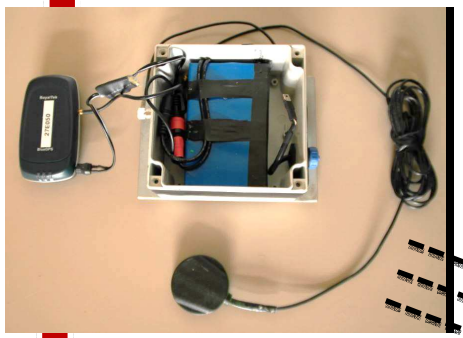
# Operational Monitoring

- Development of **solutions to get information automatically on how the mechanized field processes are carried out** to satisfy management support, logistic and production purposes

- Achievement of technologies and methods to **enable managers to keep permanently updated their field activity registers** at the enterprise

- **Enabling forms of quality certification** (especially for environment and processes, even within EPD, PEFC and CoC frameworks) based on ***reliable ex-post observations***

# Operational Monitoring: Methodology



❖ **Inference Engine** *interpreting raw data and daily updating each farm database*

❖ **Field Data Logger**
*enabling the automatic identification of the coupled implement*

❖ **Remote Server**
*Cloud Computing*

❖ **Data Transfer**
*Through GPRS transmission*

❖ **Mechanized Field Activities**
*real time monitored*

User n

User 2

Farm n

Farm 2

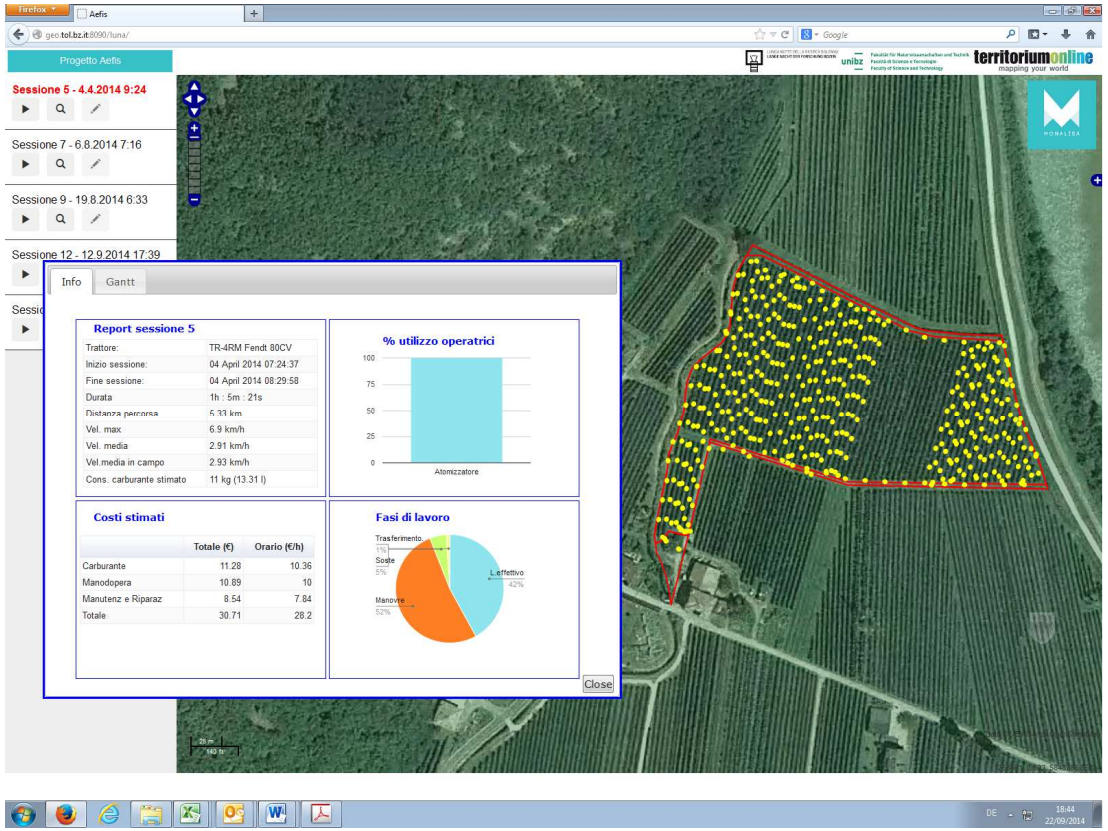
Farm 1

User 1

❖ **Farm final Users**
*access with reserved domain*

# Operational Monitoring: Results

- **Reliable capability** of self detecting and **describing farm field activities**
- Provision of **high details** for each operation reported (*work time analysis, execution dynamics, actual scheduling, cost analysis)*
- Development of a **friendly final user-interface**, easily manageable directly by farmers
- Relatively high annual costs for **data transmission** (via GPRS): to be revised the data transfer approach through WiFi connections




- **Diffusion strategy:** required the presence of a service centre to be coordinated by agricultural experts

# LAIMBURG: Handling the Variability of Quality

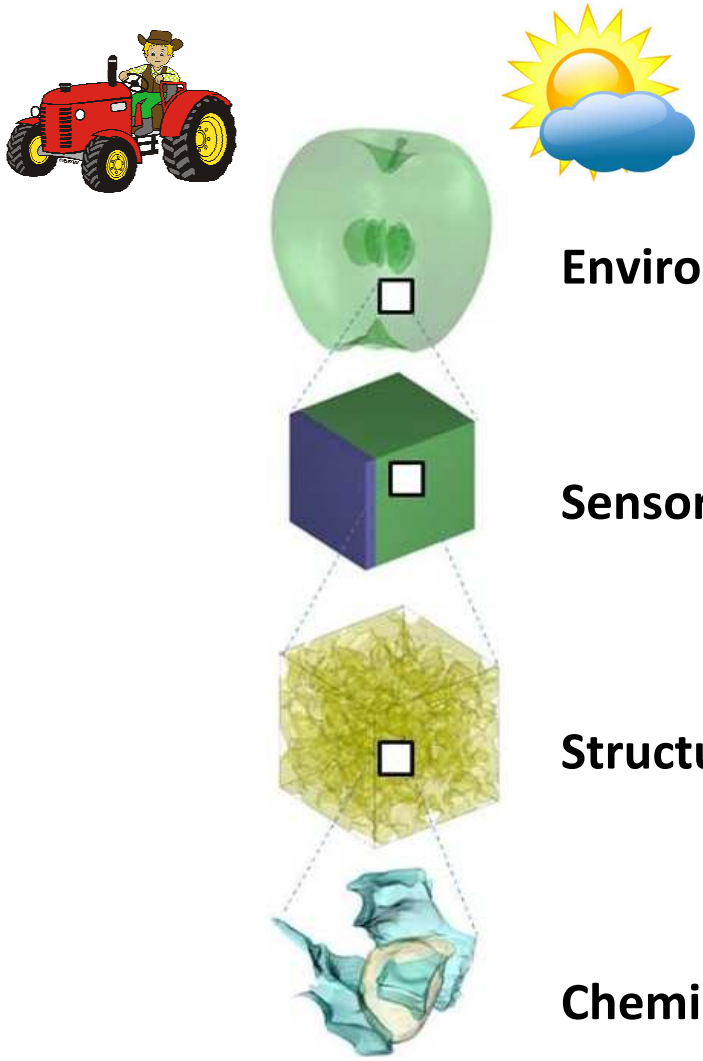
- The advanced fruit industry

  experiences significant **post-harvest losses**:

  → due to inferior quality of

  just a small harvest fraction !

# LAIMBURG: Handling the Variability of Quality



**Environmental and pre-harvest factors**

**Sensorial quality attributes**

**Structural quality level**

**Chemical quality level**

E. Herremanns, 2013

# Scope

## Cutting-edge technology scouting for:

- the NON/destructive **assessment**
- the **prediction**

…of:

**maturity**, **quality** and **storage potential**

# A) Handling Quality Variability

- Environmental factors
- Production methods
- Novel measuring methods
- **Database:** EURAC Bolzano, *Roberto Monsorno*
- **Prediction – Modelling for DSS**

  Cooperation with:

  **Wageningen University, Netherlands**

  ***Rob Schouten et Pol Tijskens***

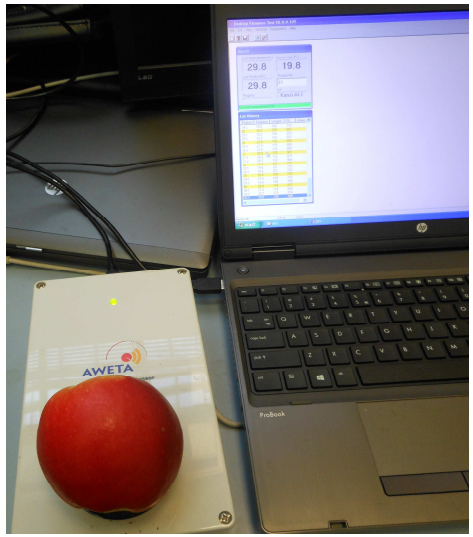
Pimprenelle (SSC, TA, FFF) at harvest

DA meter (IAD)


Amilon (Starch) at harvest

Dynamometer (FFF, Stiffness, Compression FFF)

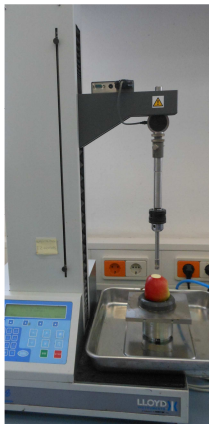
Multiplex (SFR_R; Cooperation G. Agati)




Acoustic Impact (AFS)

# Modelling changes of *Texture* in fruit flesh

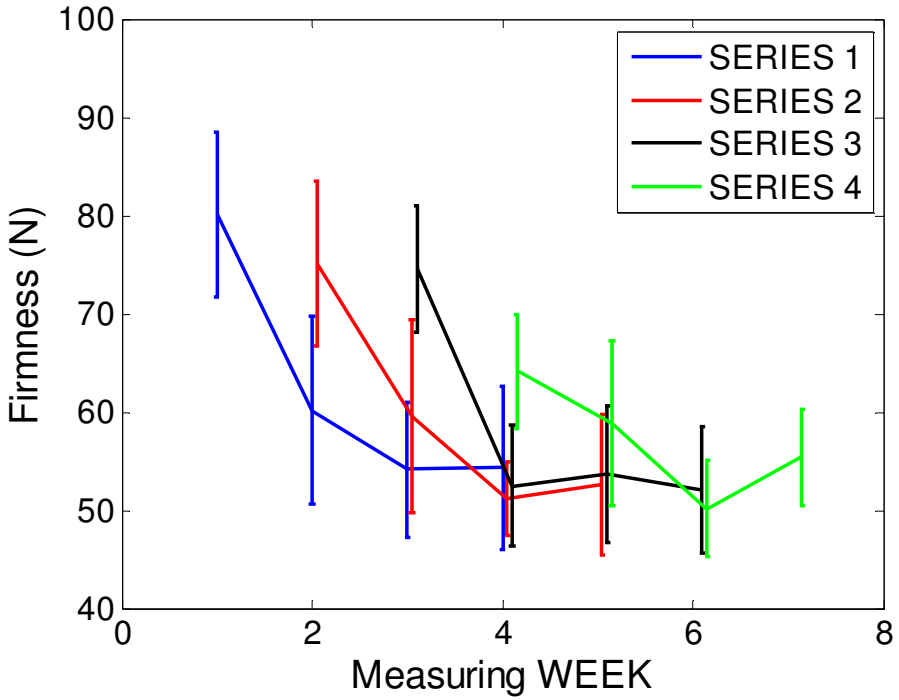
**MT firmness** – Penetrometer



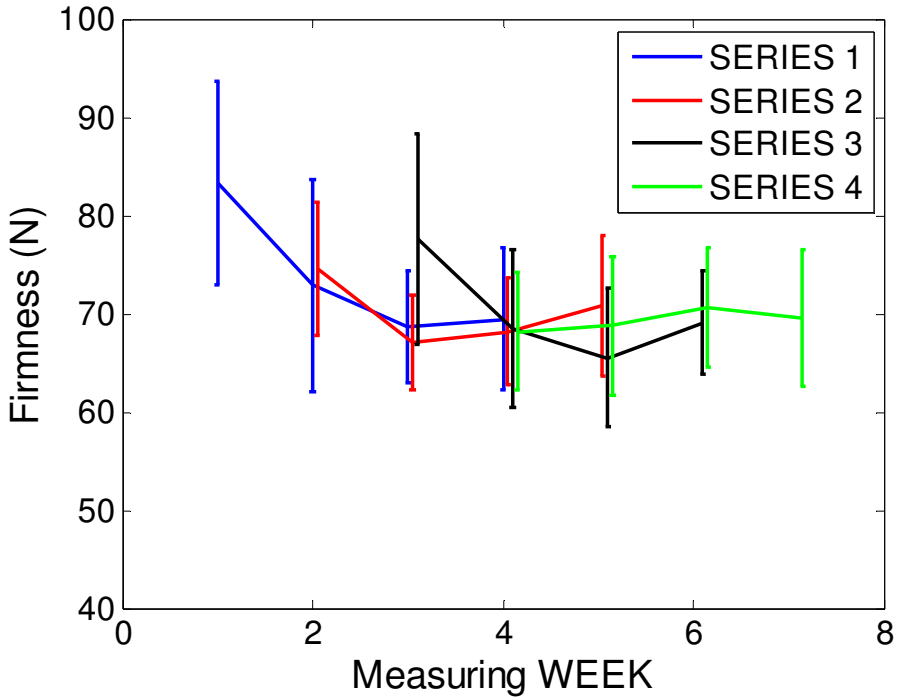
# Texture evolution in Europe

## cv. Braeburn

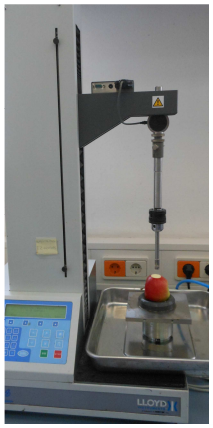
Braeburn, **Italy**




Braeburn, **Belgium**

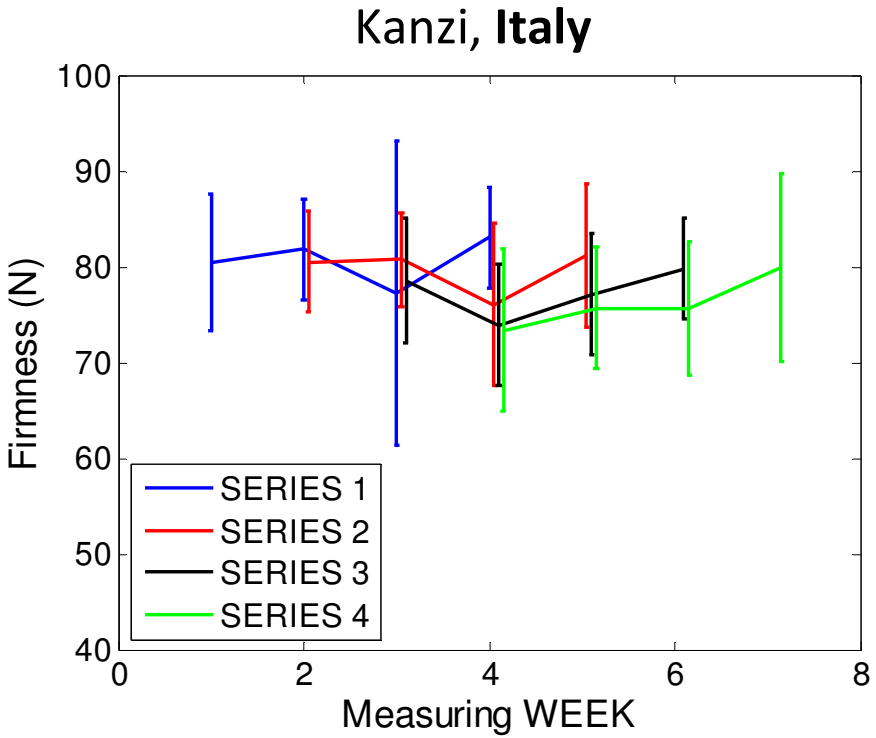


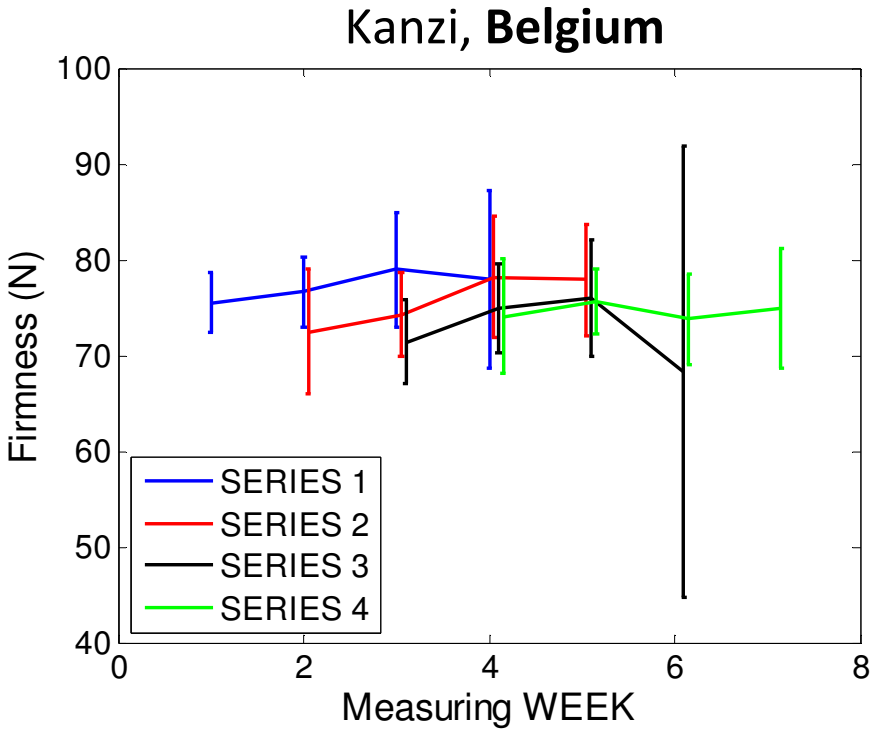

„Saeys et al.“



# Texture evolution in Europe

## cv. Nicoter/Kanzi(R)



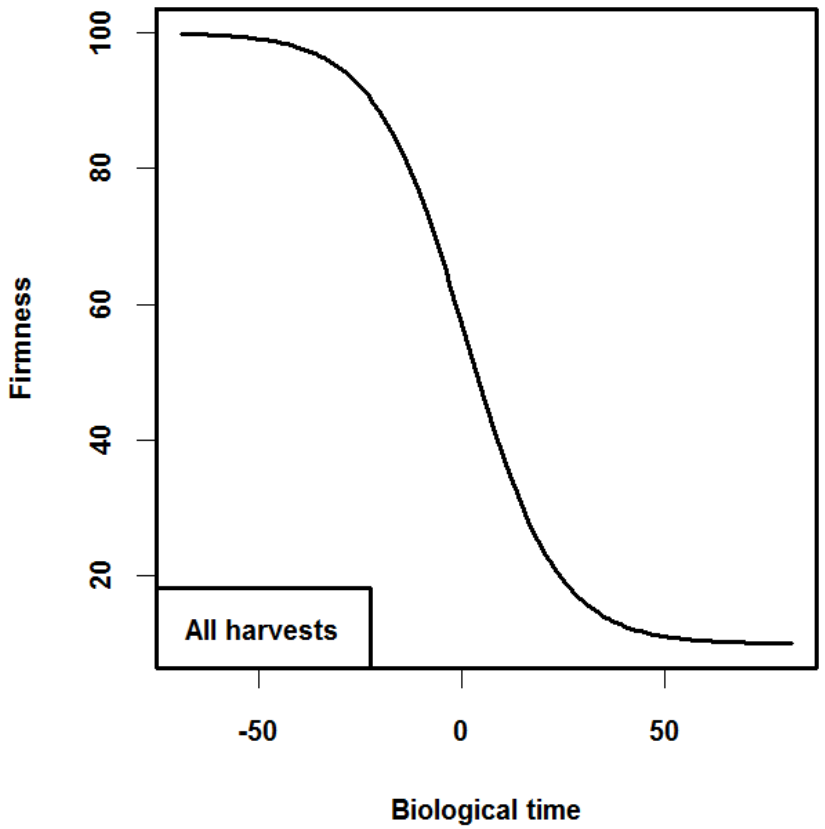

„Saeys et al.“

# HOW to mathematically model all this to get a PREDICTION system?

# Sigmoidal model of „Quality“ after harvest

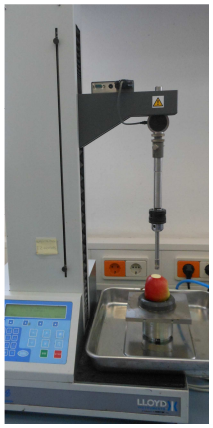
## Frequently used for

- Firmness
- Colour
- Other variables



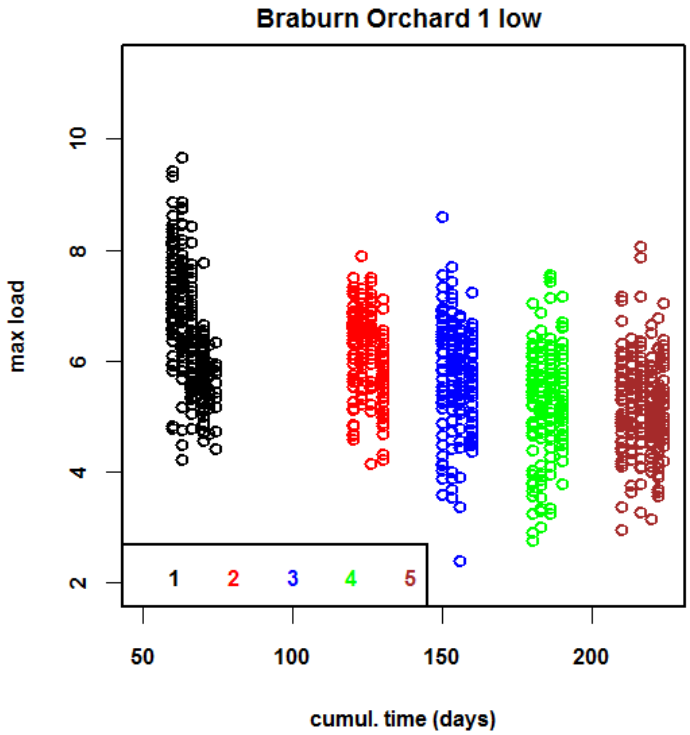

## Logistic Model firmness

$$F = \frac{F_{max} - F_{min}}{1 + e^{-k \cdot (F_{max} - F_{min}) \cdot (t + \Delta t)}} + F_{min}$$



# Texture after different storage durations

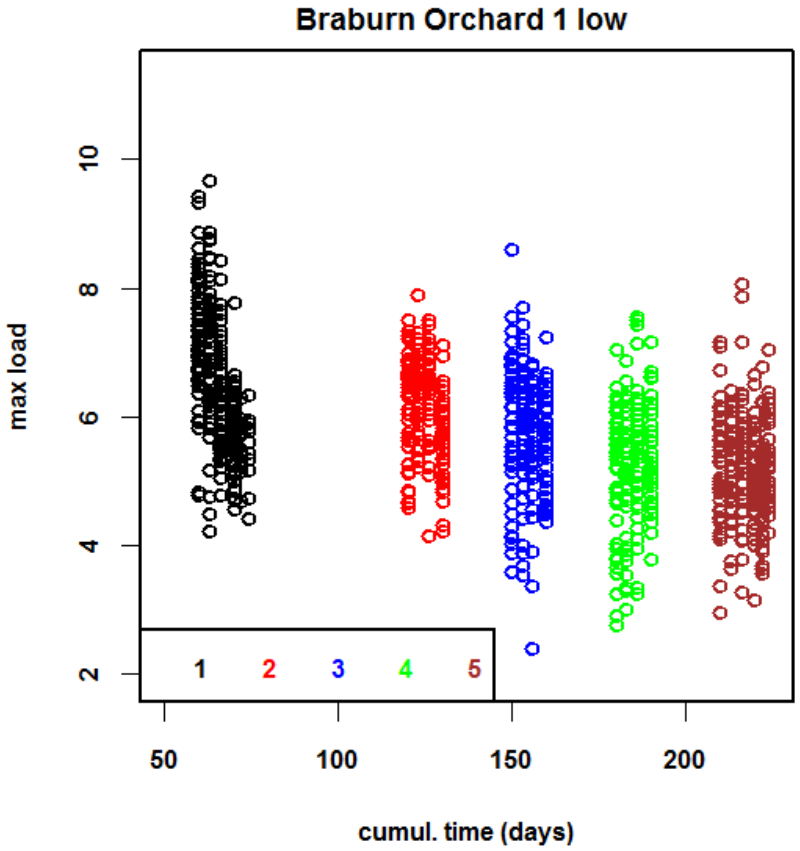
**Biological variability is higher** than the differences between different storage durations (age)



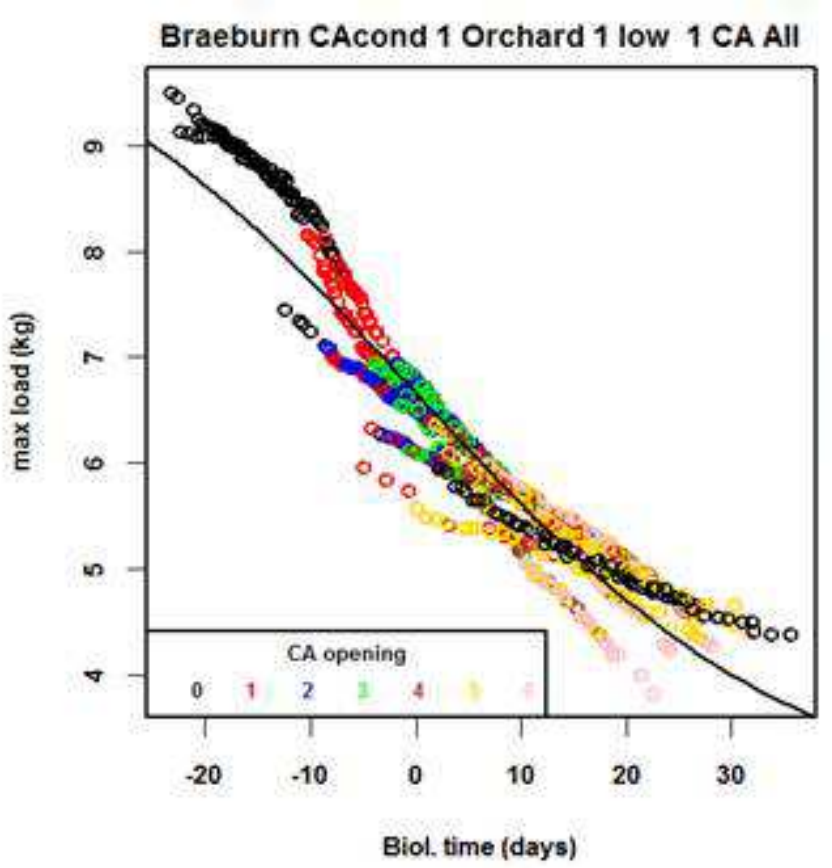
# Probelation & Quantile regression

## Biological variability and biological time

**VARIABILITY**




**PROBELATION**

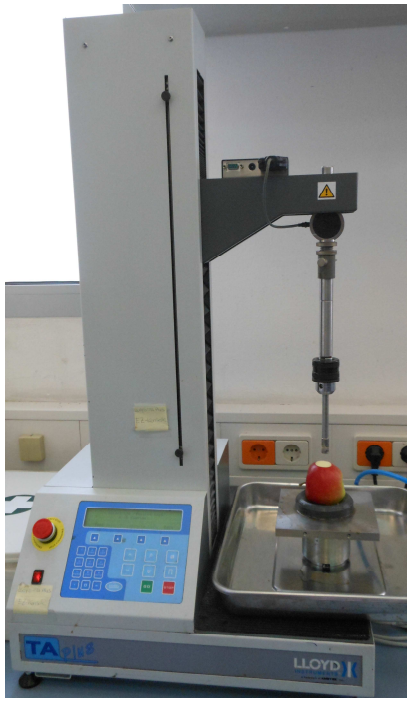



„Schouten et Tijskens“

# B) Non-destructive Texture Assessment of each fruit

**What potential**

**lays in the *top-technologies***



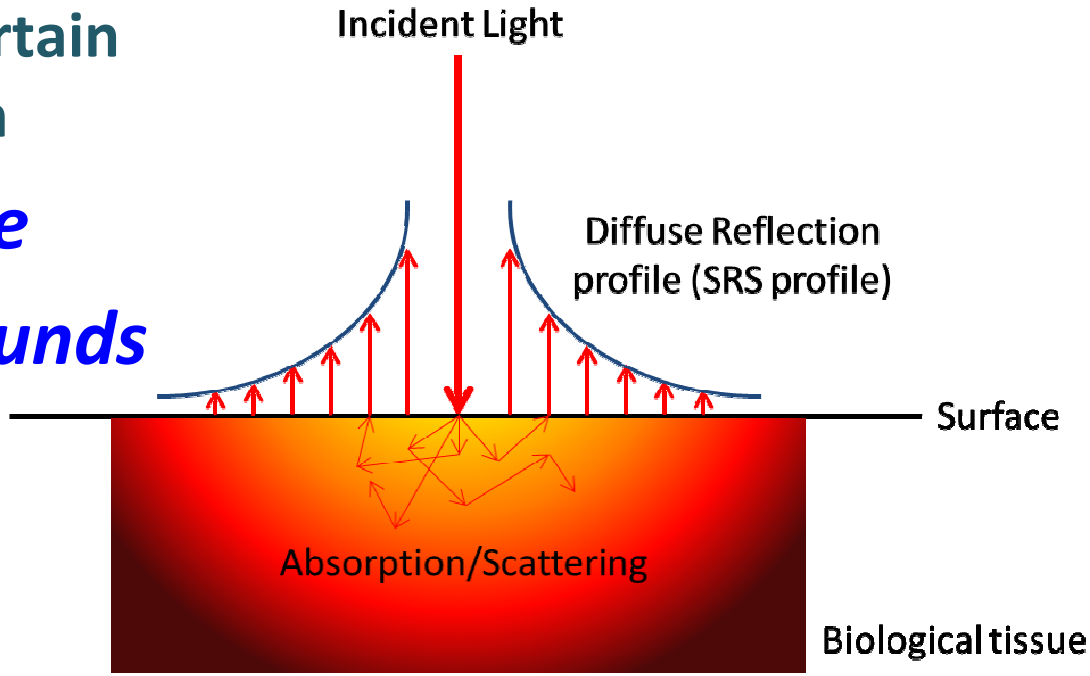

Cooperation with:

- **CNR Fotonica (Milano, I), *Spinelli & Vanoli et al.***
- **University of Leuven (Leuven, B), *Saeys et al.***

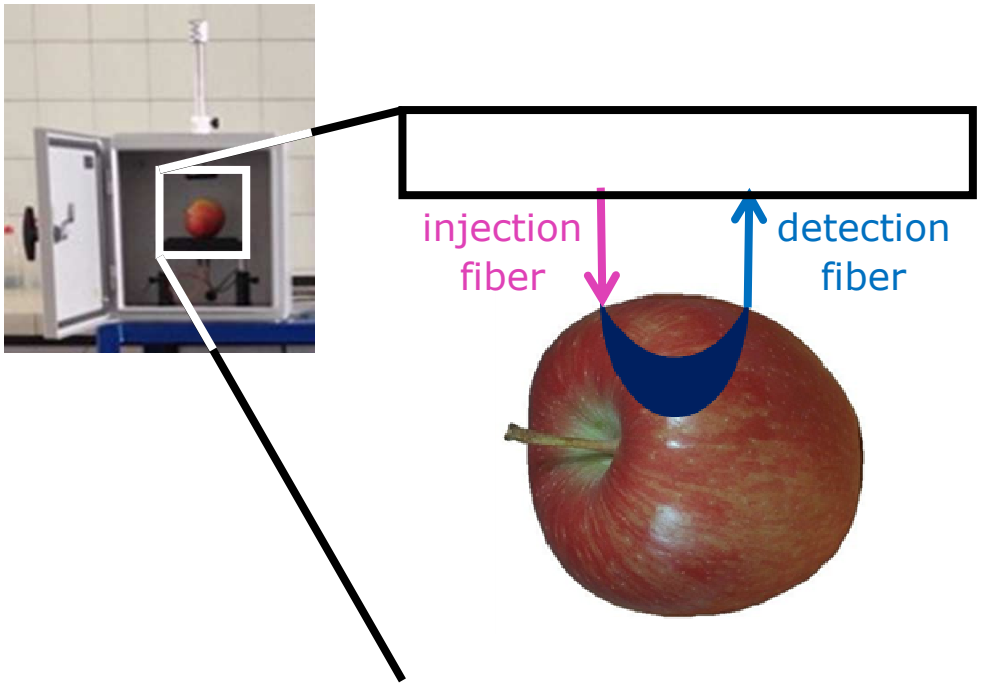
# SRS - Space Resolved Spectroscopy (Leuven)

- Light entering the (biological) sample
  - spot/fiber illumination:
  - Interactance with tissue

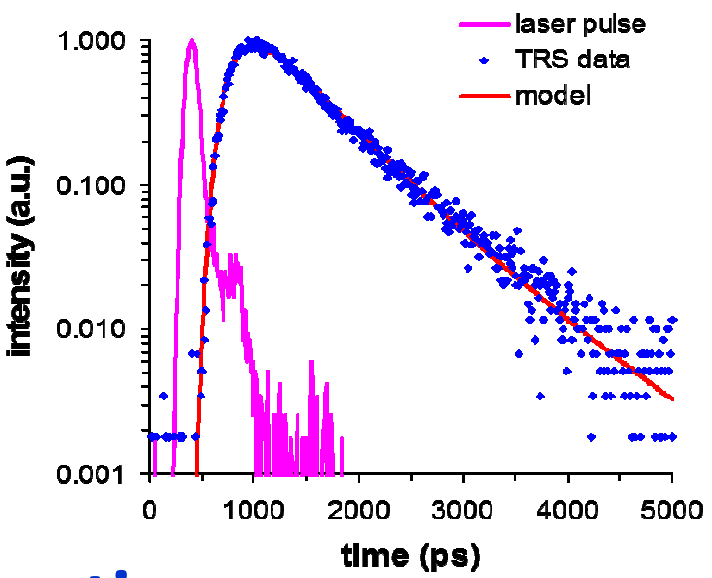
- **Collecting photons at a certain distance from illumination**
- **Scattering by *structure***
- **Absorption by *compounds***



# TRS – Time Resolved Spectroscopy (Milano)




Suitable model describes photon propagation in diffuse media




Non-destructive assessment of light-**absorption** and light-**scattering** in the fruit flesh-structure by TRS for each fruit

- Scattering coefficient independent from wavelength (assumption)
- Chlorophyll and water koncentration calculated from the absorption spectra

# C) „Scanning“ Internal Defects inside each fruit (Leuven, B)

**What potential**

**lays in the *top-technologies***

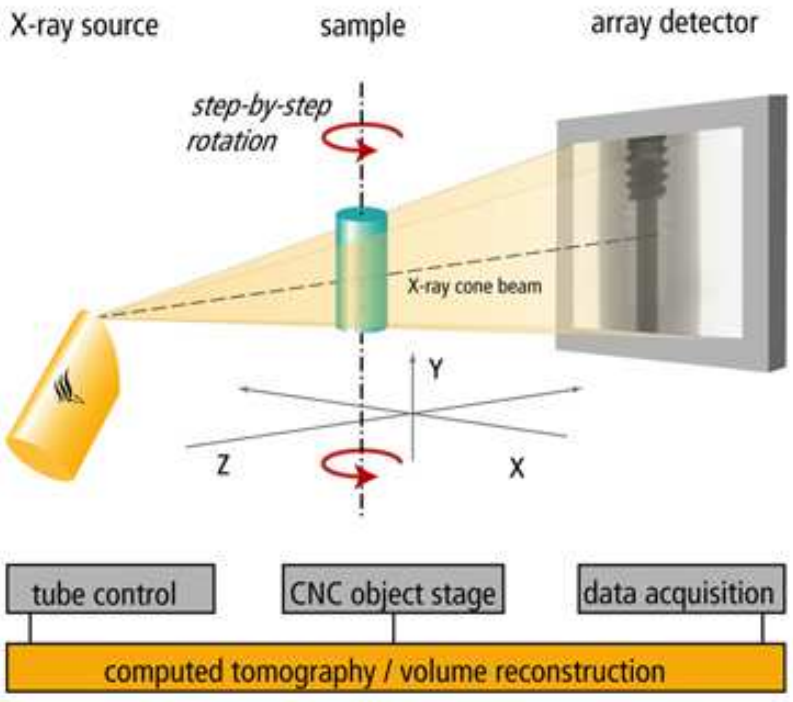
Cooperation with:

**University of Leuven (Belgium)**

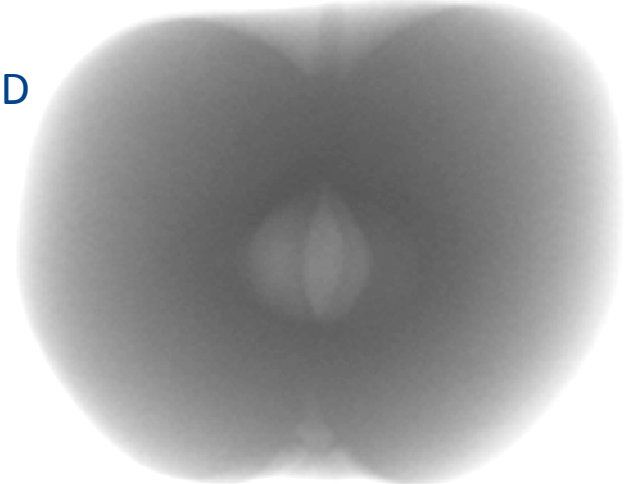
***Verboven et al.***

# Top solution? Computer tomography (CT)

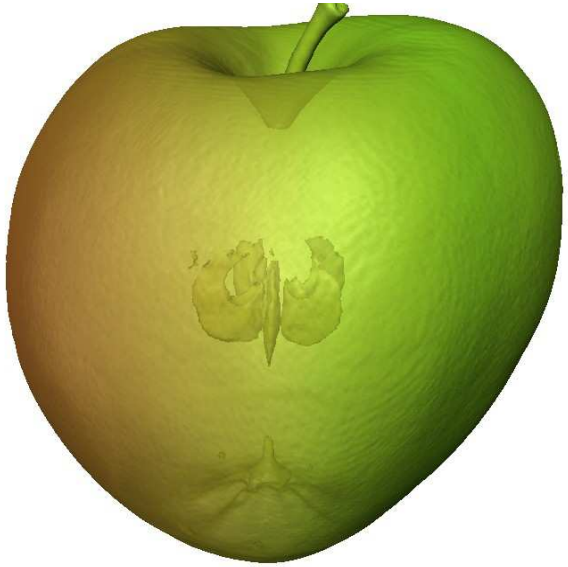
- Radiography (2D)
- Tomography (3D)




2D



3D



# Example: 3D image of internal structure of an apple

“Verboven et al.”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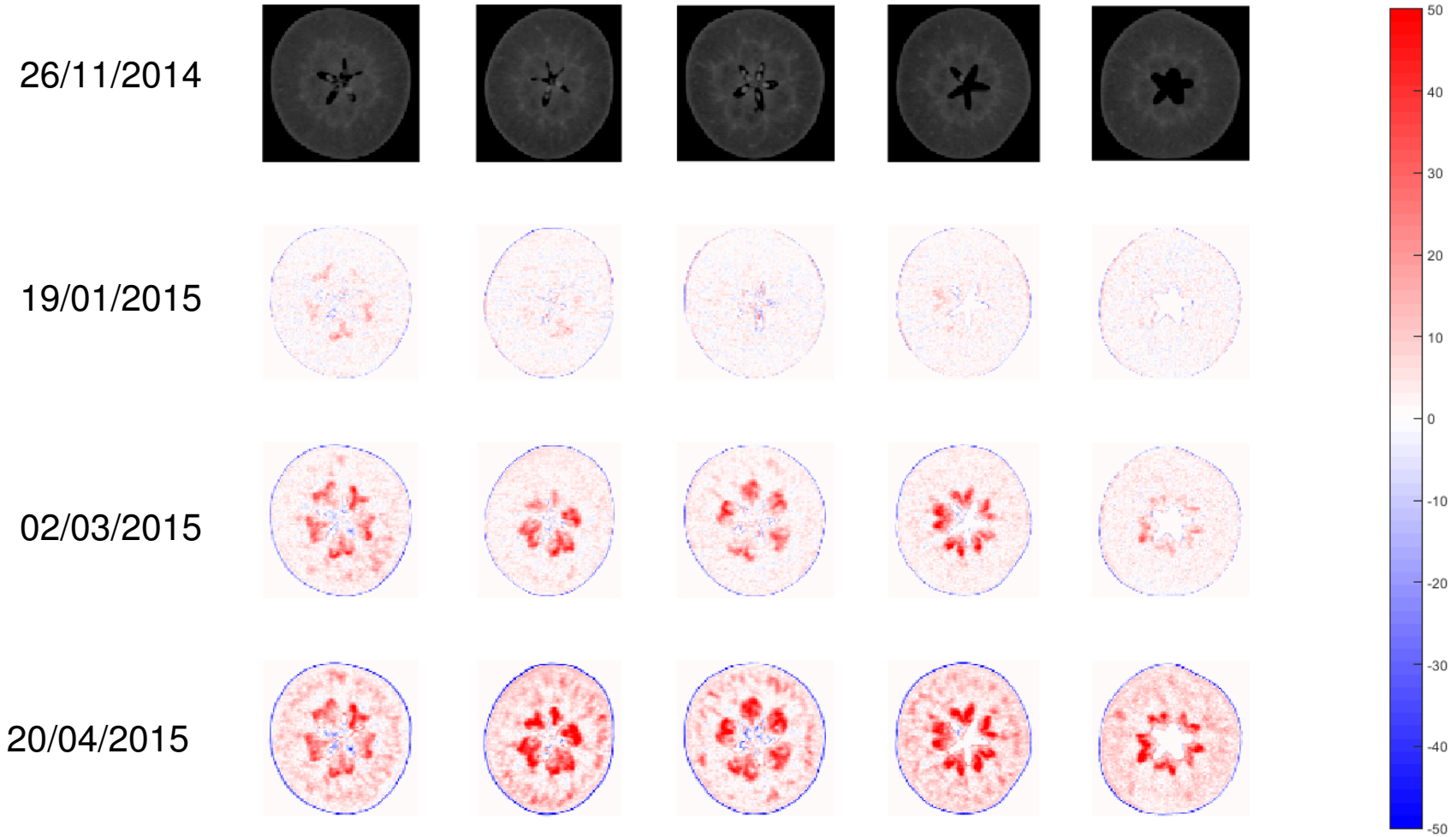
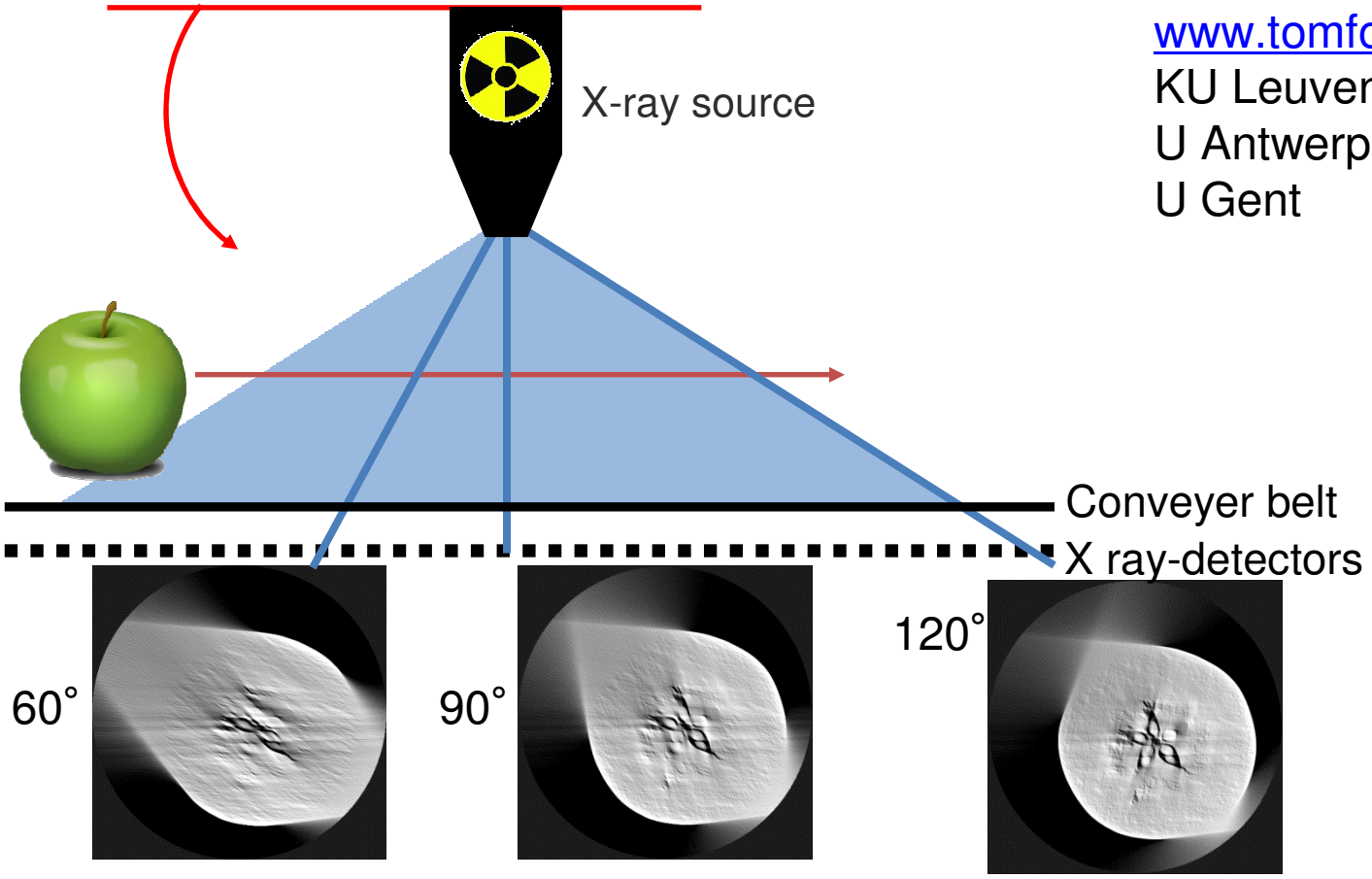
# CT Scans: Braeburn Italy, defect-inducing




"Verboven et al."

# Challenge: cost-effective inline CT

*Limited amount of data in a limited amount of time*




www.tomfood.be:
KU Leuven
U Antwerpen
U Gent

# D) Measuring bio-active compounds non-destructively of each fruit

**Which bio-active compounds are measurable with NIRS technologies**

Cooperation with:

**Res. Centre Laimburg (Italy)**

***Robatscher et al.***

# NIRS determination of **nutraceuticals** in the apple peel

- Vitamin C
- Antioxidant capacity (2 methods: FRAP, ABTS)
- Total polyphenol content
- Total anthocyanin content

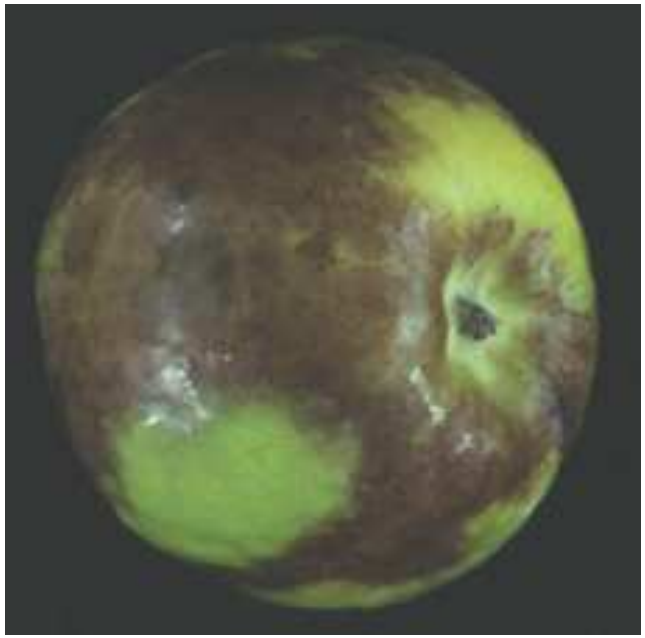
On both shaded and sun-exposed side of **27 apple cv.**



# Non-destructive measurements for apple superficial scald biomarkers

**Monitoring of the relevant biomarkers and their correlations with superficial scald in apples during storage:**

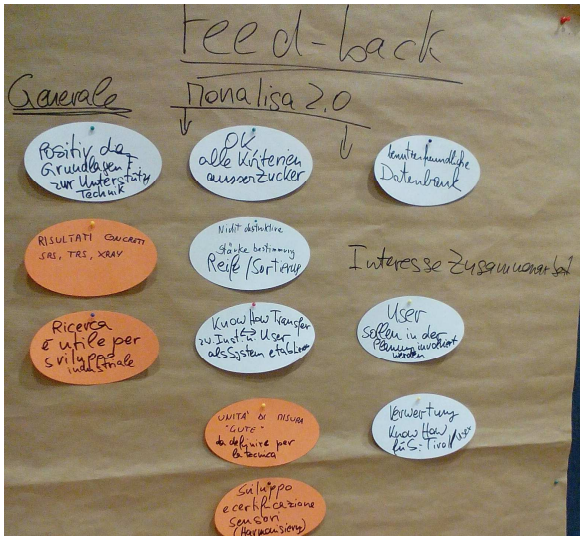
- $\alpha$-farnesene
- conjugated trienols (CTols)



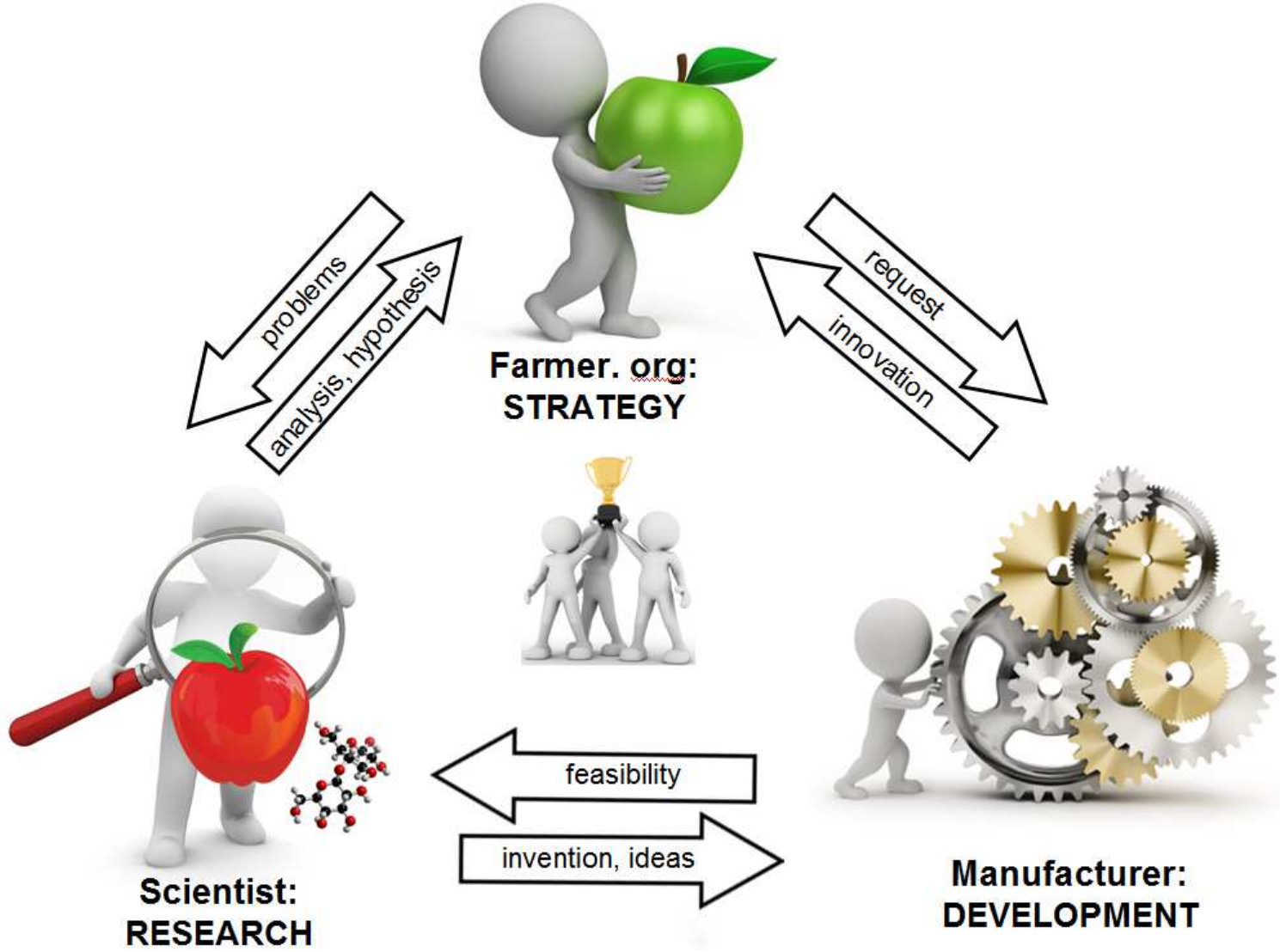
*Last but not least….*

# E) Research interacts with „Users“

- USER: device-manufacturers and farmer organizations
- To collect ideas, wishes, opinions and suggestions from USER on:
  - -Current objectives
  - -Challenges, gaps
  - -Feed-back and Future collaboration


# The User Interaction



# Thank you for your kind attention!

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