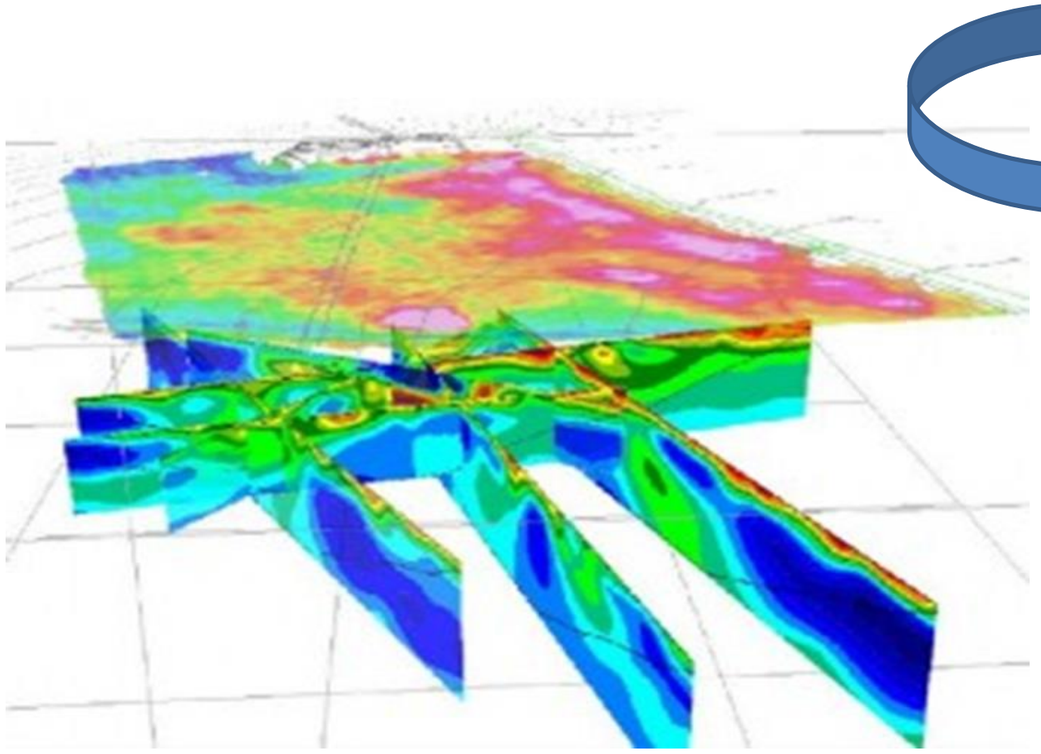
Roberta Rossi, Ph.D

Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria (CREA)

Centro di ricerca Zootecnia e Acquacoltura (CREA- ZA)

Sede di servizio : Bella

Soil proximal sensing



Geophysical prospection

Contribute on the use
Resistivity
Methods in Agriculture

crea
Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria

Soil electrical resistivity (ER)

or its inverse *Soil electrical conductivity* ***(EC)***

Is one of the most used proxies of soil spatial variability in agriculture

ER ρ (Ohm m)

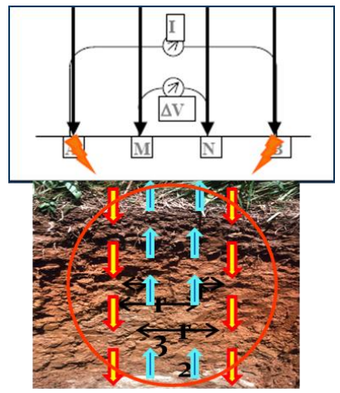
Is a measure of how strongly a given material opposes the flow of electric current.

$$\rho(Ohm\ m) = K(\Delta V / I)$$

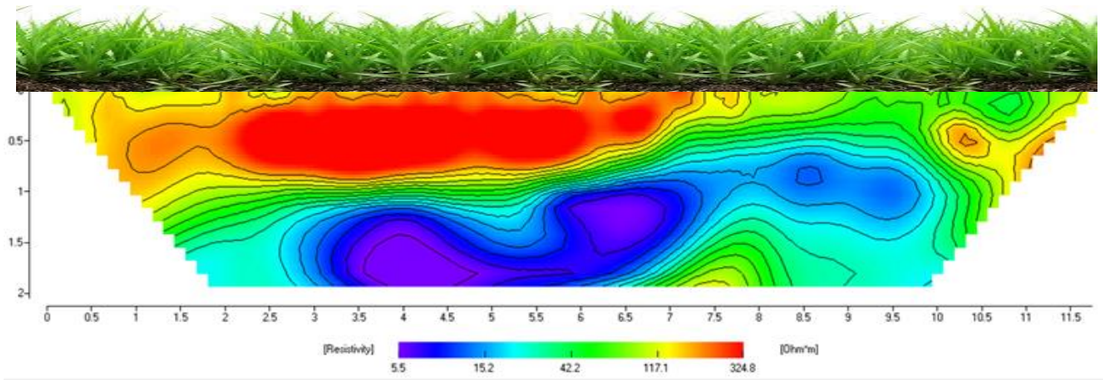
How is it measured ?

Injecting an artificial current unto the ground

Measuring the Potential drop ΔV

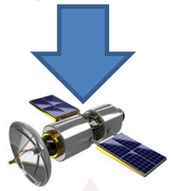


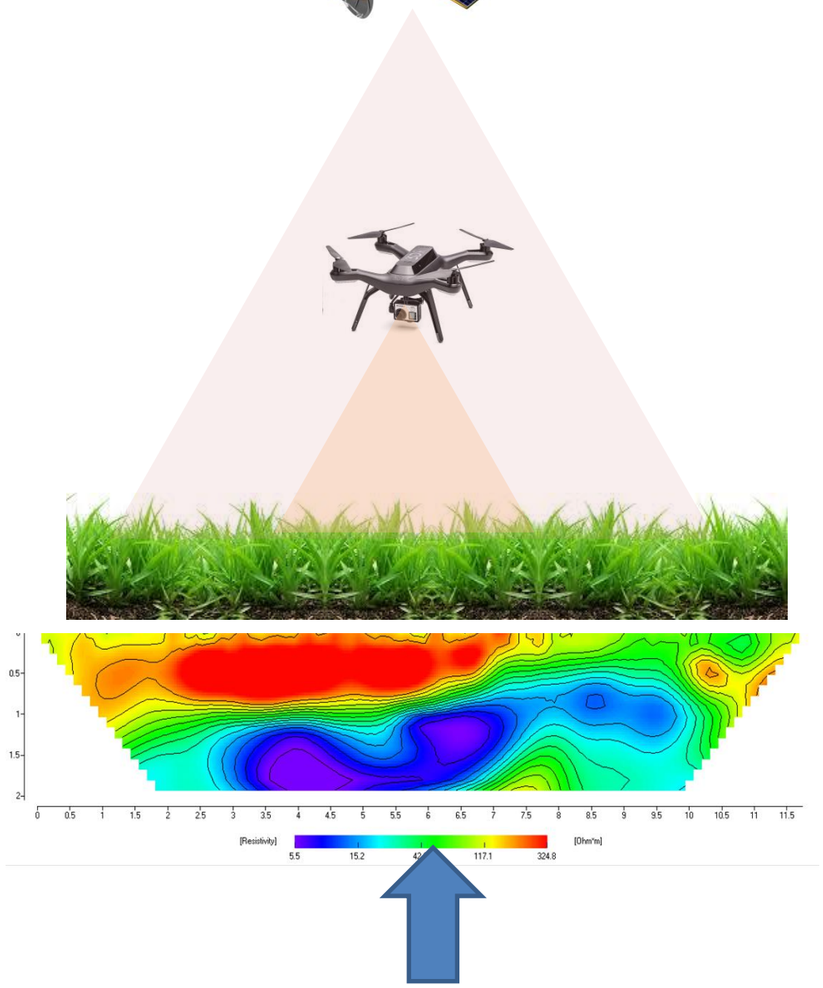
Oversimplifying : The final result is 2D or 3D map of subsurface resistivity distribution



Electrical resistivity tomography Is a **soil imaging technique** that can complement crop sensing :

Crop sensing





Soil sensing

Resistivity Is correlated to several soil properties

Conductive materials

- ✓ Clay content
- ✓ Salinity
- ✓ CEC
- ✓ Water content

Resistive materials:

- ✓ Rock fragments
- ✓ Hardpans
- ✓ Voids (soil porosity)

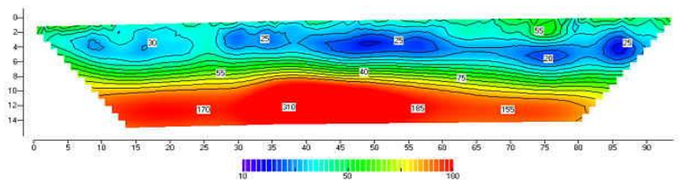
Due to overlapping ranges ground-truth calibration is always needed

These soil imaging techniques have been extensively used on arable lands much less has been done in grasslands where they can be a **useful complement of remote sensing data** to **help discerning <u>the causes of crop variability : soil-based constrained to plant productivity</u>**

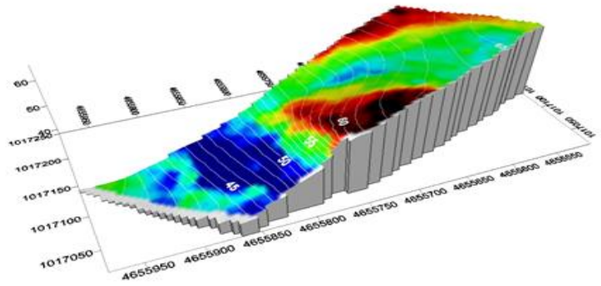
DC – resistivity survey

Field Methodology

Static equipment : metal electrods in line



Moving electrodes: toothed wheels



Resistivity methods : static systems

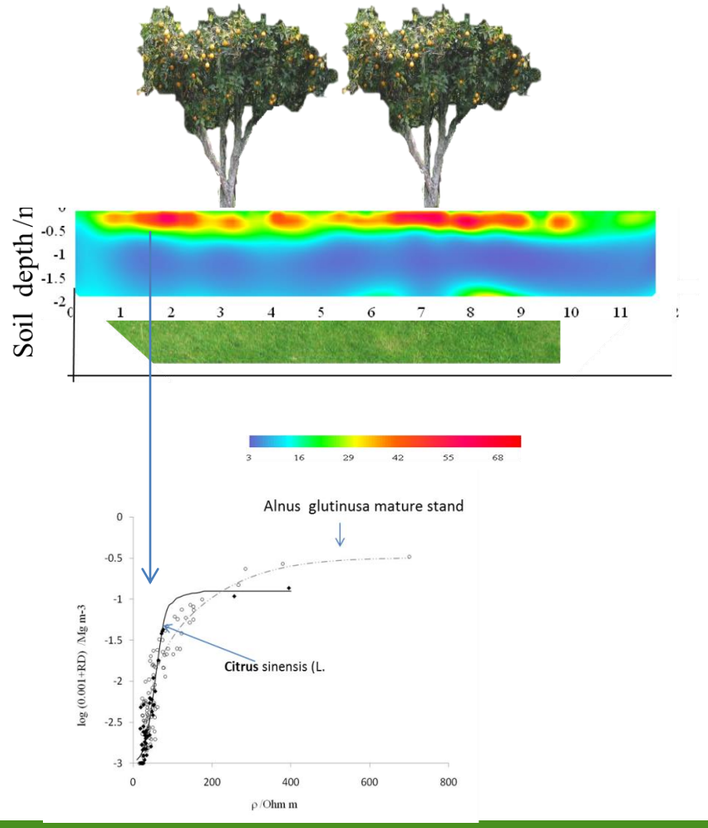
Our team started in **2008** with **static equipment** for high resolution 2D and 3D mapping of soil biophysical properties

- ✓ Amato, M., Basso, B., Celano, G., Bitella, G., Morelli, G., & **Rossi**, R. (2008). In situ detection of tree **root distribution** and biomass by multi-electrode resistivity imaging. *Tree physiology*, *28*(10), 1441-1448.
- ✓ **Rossi**, R., Amato, M., Bitella, G., Bochicchio, R., Ferreira Gomes, J. J., Lovelli, S., ... & Favale, P. (2011). Electrical resistivity tomography as a non-destructive method for mapping **root biomass** in an orchard. European Journal of Soil Science, 62(2), 206-215.
- ✓ Amato, M., Bitella, G., **Rossi**, R., Gómez, J. A., Lovelli, S., & Gomes, J. J. F. (2009). Multi-electrode 3D resistivity imaging of **alfalfa root zone**. European Journal of Agronomy, 31(4), 213-222
- ✓ **Rossi**, R., Amato, M., Pollice, A., Bitella, G., Gomes, J. J., Bochicchio, R., & Baronti, S. (2013). Electrical resistivity tomography to detect the effects of **tillage** in a soil with a variable **rock fragment** content. *European Journal of Soil Science*, *64*(2), 239-248.

Plant roots research

trees

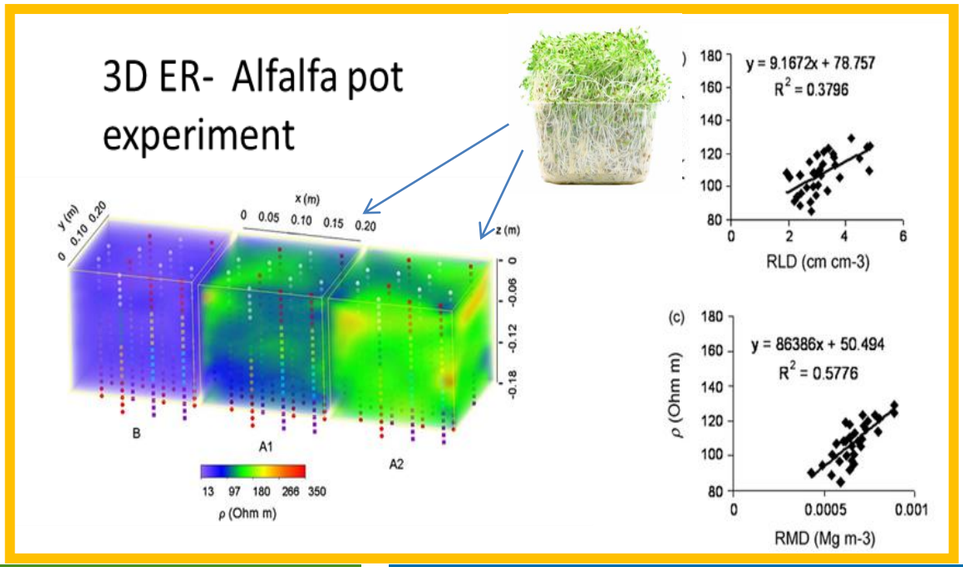
Quantification of tree roots biomass



Sampling effort is a key issue

Forage crops

Herbaceous roots : alfalfa seedlings



Background soil variability

Imaging soil features capable of altering roots distribution (soil structure)

Imaging tillage effects

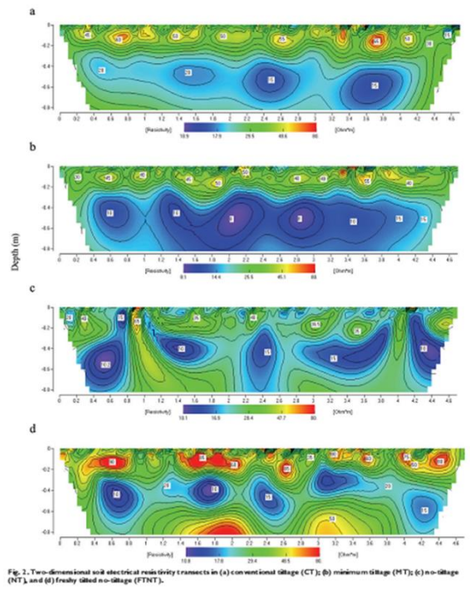


Fig. 2. Two-dimensional soil electrical resistivity transects in (a) conventional tillage (CT); (b) minimum tillage (MT); (c) no-tillage (NT), and (d) freshly tilled no-tillage (FTNT).

Static systems: points of strength and weakness

Flexible resolution (depends on the distance between electrodes)

From centimetric targets (sol cracks / roots) to gravel lenses, water table , buried channels

- ✓ Labour demanding
- ✓ Poor data coverage
- ✓ Require optimal soil-electrodes contact

- ✓ Suitable for detailed studies , for time-lapse measurements
- ✓ The poor data coverage and the labour required makes it unsuitable for mapping variability at field /plot scale

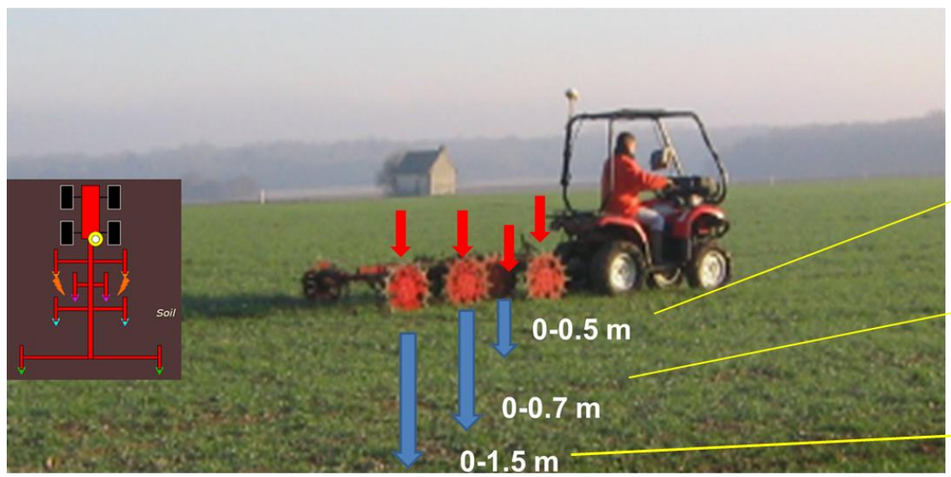
….Than we moved to dynamic systems……

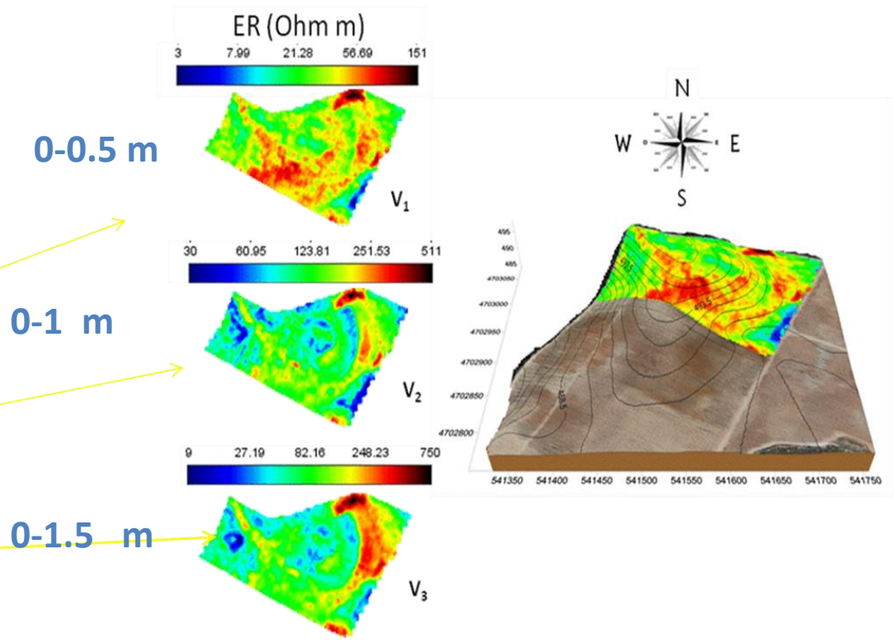
Rossi, Roberta, et al. "Using an automatic resistivity profiler soil sensor on-the-go in precision viticulture." *Sensors* 13.1 (2013): 1121-1136.
Rossi, R., Pollice, A., Bitella, G., Bochicchio, R., D'Antonio, A., Alromeed, A. A., ... & Amato, M. (2015). Soil bulk electrical resistivity and forage ground cover: nonlinear models in an alfalfa (Medicago sativa L.) case study. *Italian Journal of Agronomy*, *10*(4), 215-219.

Moving systems are used to map resistivity at field scale

The fixed electrodes (*nails*) are replaced by **toothed wheels towed across the field** to obtain a wide coverage at **multiple depths** . It slices the soil profile in three horizontal **parallel planes (soil strata 0-0.5 m; 0-1 m; 1.5 m)**

ARP -Automatic Resistivity Profiling- (ARP patented, Geocarta society, Paris, France)



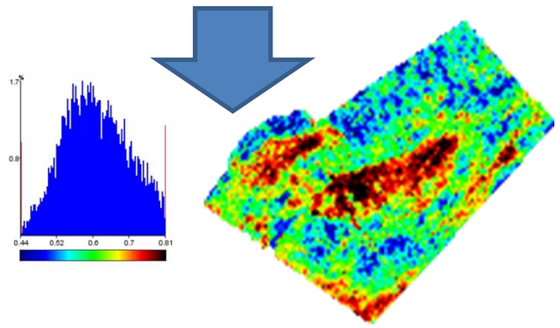


- ✓ The system is very fast an average of 40 ha can be mapped in day of work real time maps of ER to be used as a basis for **directed sampling schemes**

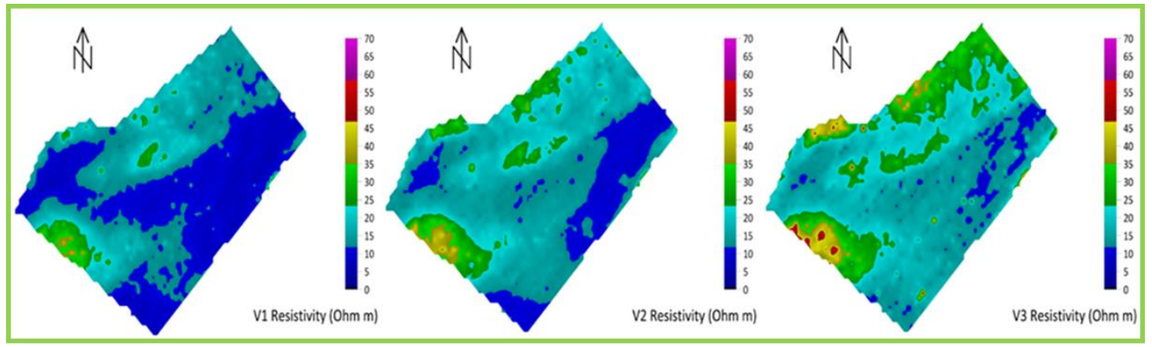
- ✓ Information on **deep soil variability can be very important for deep rooted perennials that rely on stored water …. nevertheless it is often overlooked due to methodological difficulties**

Case study: coupling soil information and crop sensing in a forage crop : Non-linear relationship between NDVI and RESISTIVITY in Alfalfa

NDVI fall 2013



Multidepth soil Resistivity



0.5 m 1 m 1.5 m

We regressed NDVI and ER at 1.5 m and applied a target sampling strategies

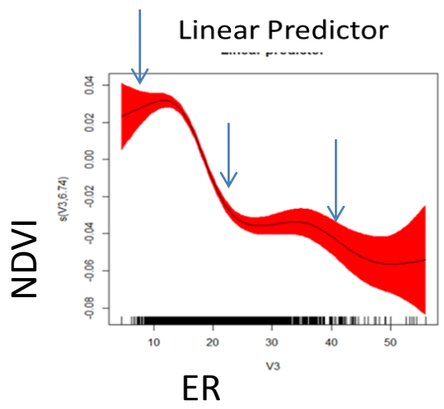
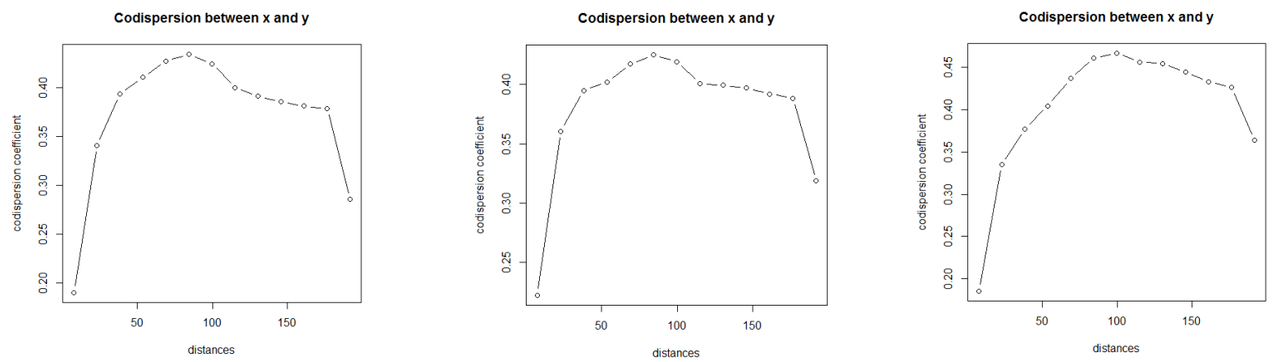


Figure 9 Left - Field zonation . From left 1) pooled GAM estimated smoothing

6 Sampling sites (soil trenches) were chosen along a gradient of ER and in places where the ER-NDVI relationship changed

Bivariate measure of spatial association between variables

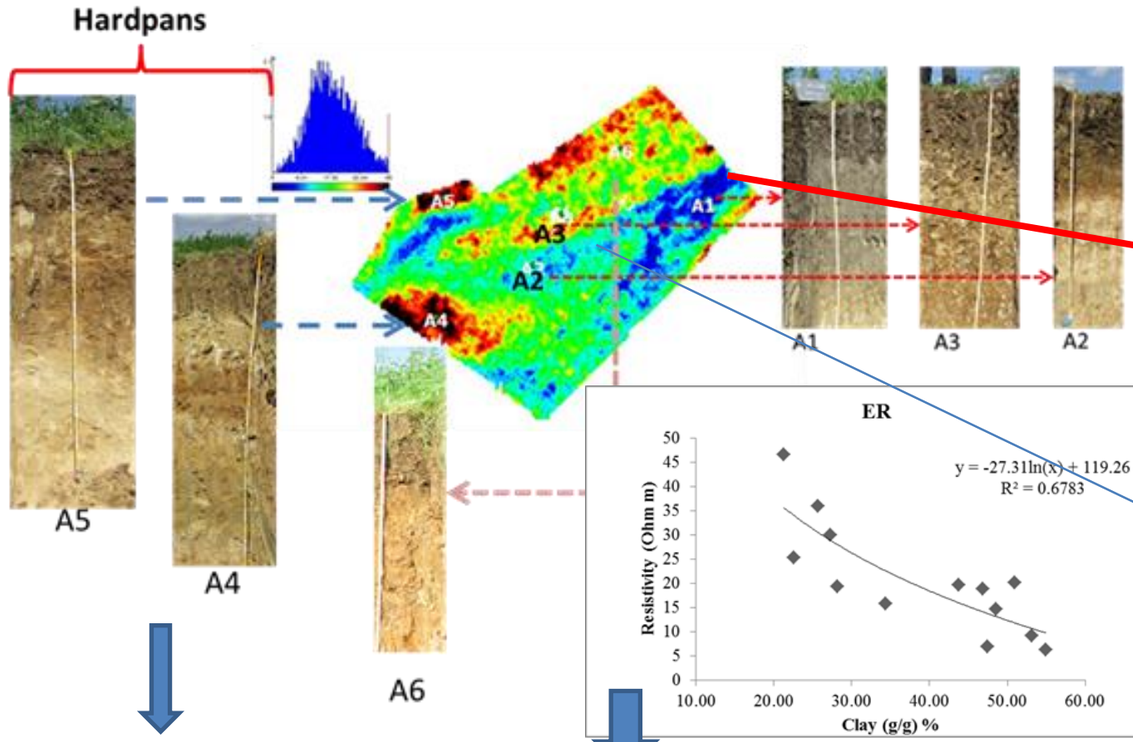


ER and NDVI showed a fairly similar spatial structure especially if the deepest resistivity is considered .

ER was correlated to the presence of permanent soil features

This 7 ha field showed a high soil variability within relatively short scale

Different texture

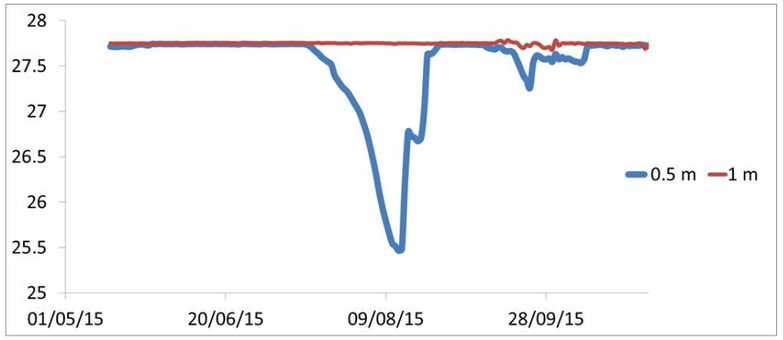


ER variation was related to texture

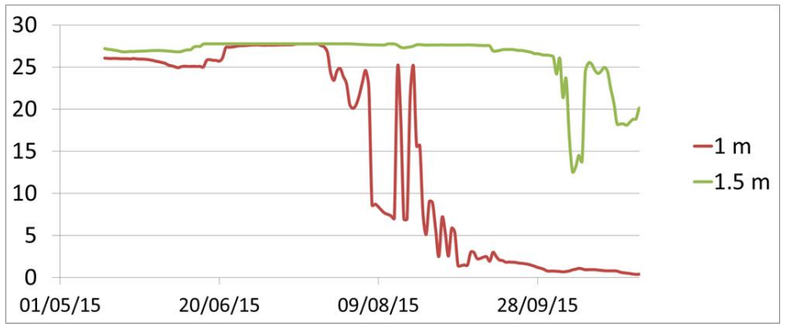
Different available water content

Profile dewatering during the growing season

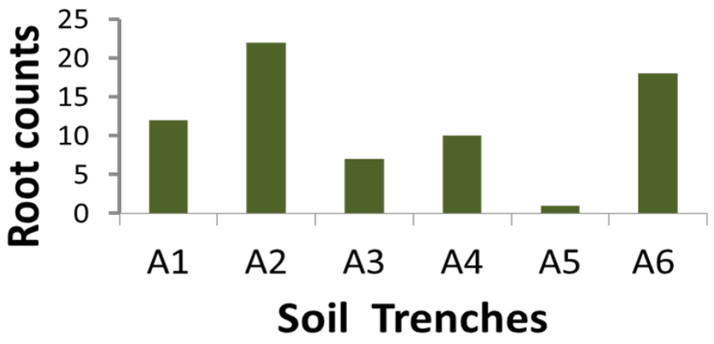
A1



A2



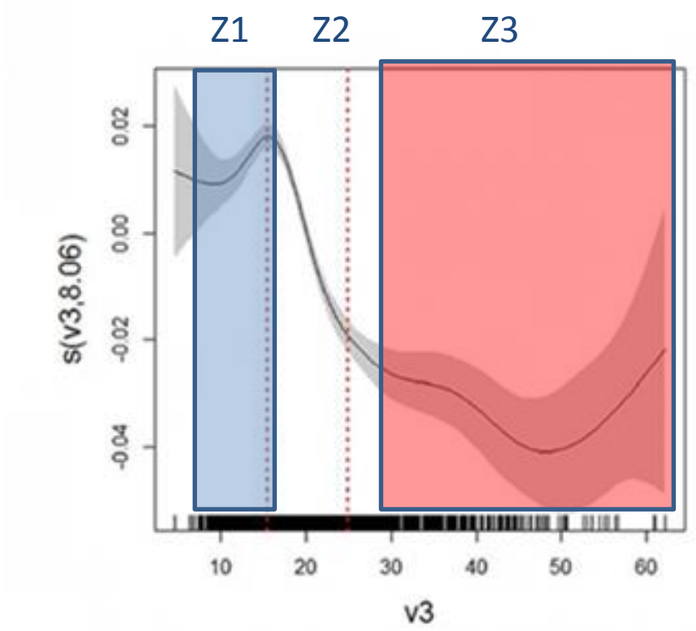
Different root density in deep strata (< 1.5)

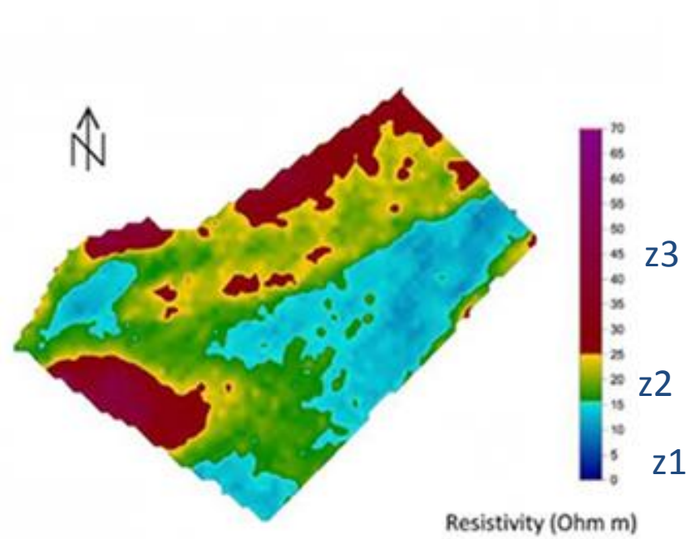


- **Identify Texture related variability allowed**:
- Optimized root/soil sampling strategy
- Optimal placement of monodimensional sensors (moisture probes)

NDVI was measured 4 times across 2 years showed a consistent non-linear relationship with resistivity . The non –linearity between NDVI and ER was used as a basis for field zonation

We split the field in areas with different SOIL- PLANT relationship, possibly requiring different management options





: Zone 1 V3 < 15.5 Ohm m) poorly drained soils **risk of waterlogging** in wet years (precision drainage / precision planting)

Zone ii. (15.5 Ohm m < V3 < 25 Ohm m) **ER acts almost linearly** and consistently on NDVI , ER can be used as prescription map

. Zone iii. (V3 > 25 Ohm m) the area of **the hardpans** (non alterable soii features/precision planting / conservative water use)

Conclusions

This preliminary data support the hypothesis that perennials like alfalfa tend to **develop persistent spatial features linked to deep soil variability,** addressing the importance of using multi-depth soil information for designing specific precision farming strategies for **perennial crops**.

Conclusions

- ✓ **Proximal soil sensing can integrate crop sensing and help discerning the causes of variability ; soil related constraint to plant productivity**

- ✓ **Moving systems are very fast and efficient : can be used to map several hectars in day of work, the fast data processing (few minutes) is compatible with a post-survey soil sampling strategy**

- ✓ **Soil maps can be used to optimize soil sampling and for the optimal placement of monodimensional sensors (moisture probes)**

- ✓ **Information on deep soil variability can be important for perennials such as alfalfa that rely on deep stored water . This information is often overlooked because of methodological difficulties . Can be use to bridge a gap to design site-specific management options for perennials**

High resolution resistivity mapping in Grassland science : quick overview

Environmental monitoring

- N /waste / pesticide leaching

C balance; GHGs fluxes

Precision farming

- Management-zones delineation

Novel frontiers : Field Phenotyping

build-up informed experimental designs

improve the efficiency of existing agronomic/phenotyping field trials

Especially if roots trait are involved

crea
Consiglio per la ricerca in agricoltura
e l'analisi dell'economia agraria

Thank you for your attention