Cosmic ray neutron sensing in cropped field:
challenges and progress

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Outline

- ## Motivation
  - Agricultural water management

- ## What are the challenges?
  - The role of biomass

- ## What is the progress?
  - Paper in prep.

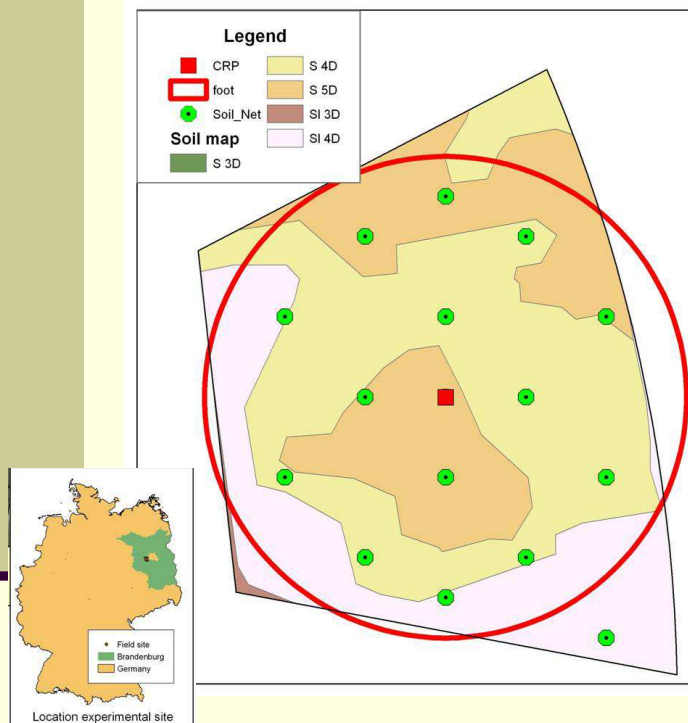**Uni Potsdam (Germany)**

S.E.Oswald
C.A.Rivera Villareyes
G.Baroni

- ❑ 2010 start
- ❑ Four Cosmic ray neutron probes

UFZ Leipzig (Germany)
S.Zacharias and U.Wollschläger

Motivation

Challenges   Progress

Legend
CRP — S 4D
foot — S 5D
Soil_Net — SI 3D
Soil map — SI 4D
S 3D

Location experimental site

- cropped field close to university
- Altitude 40 m a.s.l.
- Relatively flat
- Area: ~ 30 ha
- sand >75%; clay <15%
- Groundwater < 5 m
- 2 CRS
- 18 points FDR

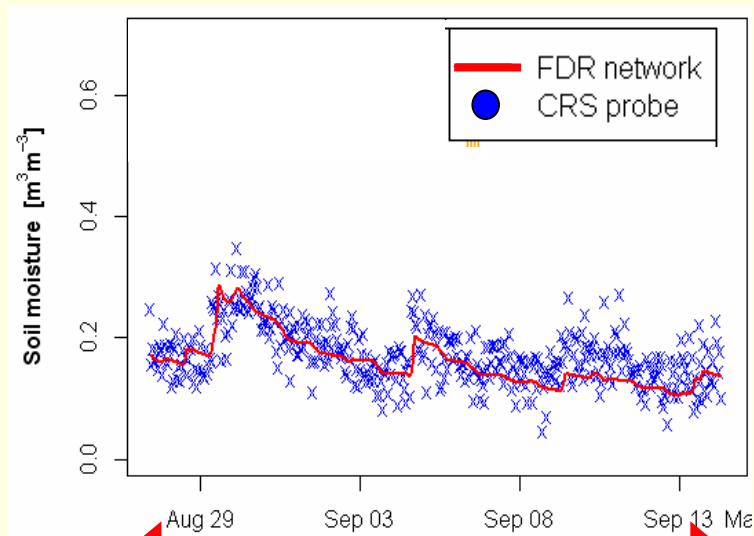Is it possible to use the Cosmic-Ray neutron sensing for agricultural water management? e.g. irrigation
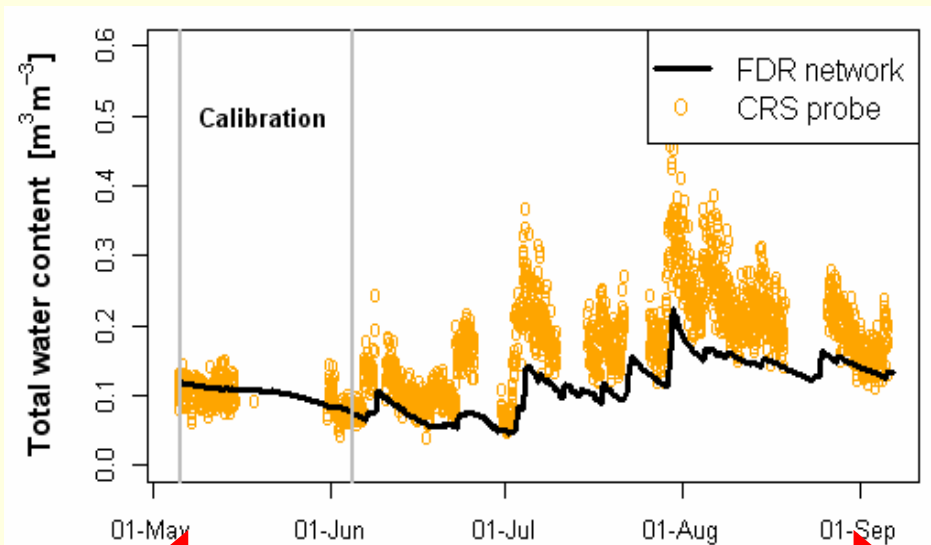
First results…

Rivera Villareyes et al. (2011)

Two weeks (~constant biomass)

But in a longer period…
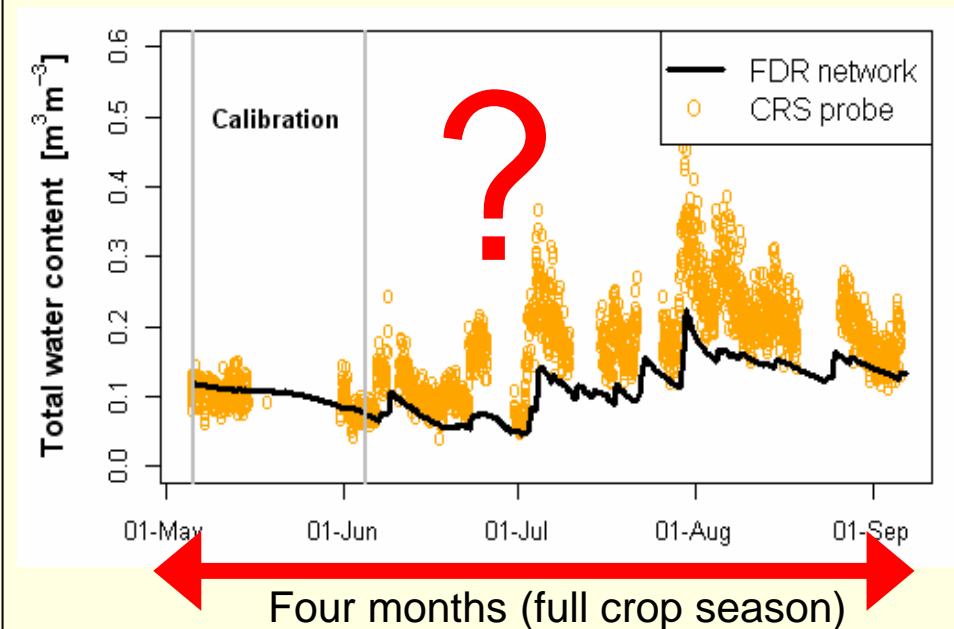
Systematic deviation

Four months (full crop season)

- Work conducted by Carlos

- Calibration approaches
  - C.R.Villareyes et al., 2012

- Inverse modeling for effective soil parameters
  - C.R.Villareyes et al., 2014 under review

- PhD Thesis
  - C.R.Villareyes, 2014

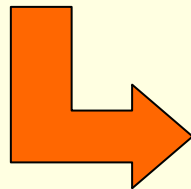### But in a longer period…

Systematic deviation

Four months (full crop season)

$$H_p = f(N, p)$$

H pool in the footprint

(30 ha 10-70 cm depth)

Neutron counts

parameters

Many sources of H

By T.Franz

Transient
Quasi-static
Static

1. Water Vapor
2. Built-up
3. Vegetation
4. Intercepted
5. Surface Water
6. Layer of Water
7. Soil Moisture
8. Lattice Water
9. Soil Carbon Compounds

- Two possible approaches

(1) Static hydrogen pool can be intrinsic considered in the local calibration

$$H_{\theta_v} = f(N, p)$$

$$H_{\theta_v} = f(N, p(t))$$

(2) Measurements of all the H sources except the target (e.g. soil moisture)

$$H_{\theta_v} = f(N, p) - \sum_1^k H_i$$

$$H_{\theta_v} = f(N, p) - \sum_1^k H_i(t)$$

In case more than one time-varying H pool?
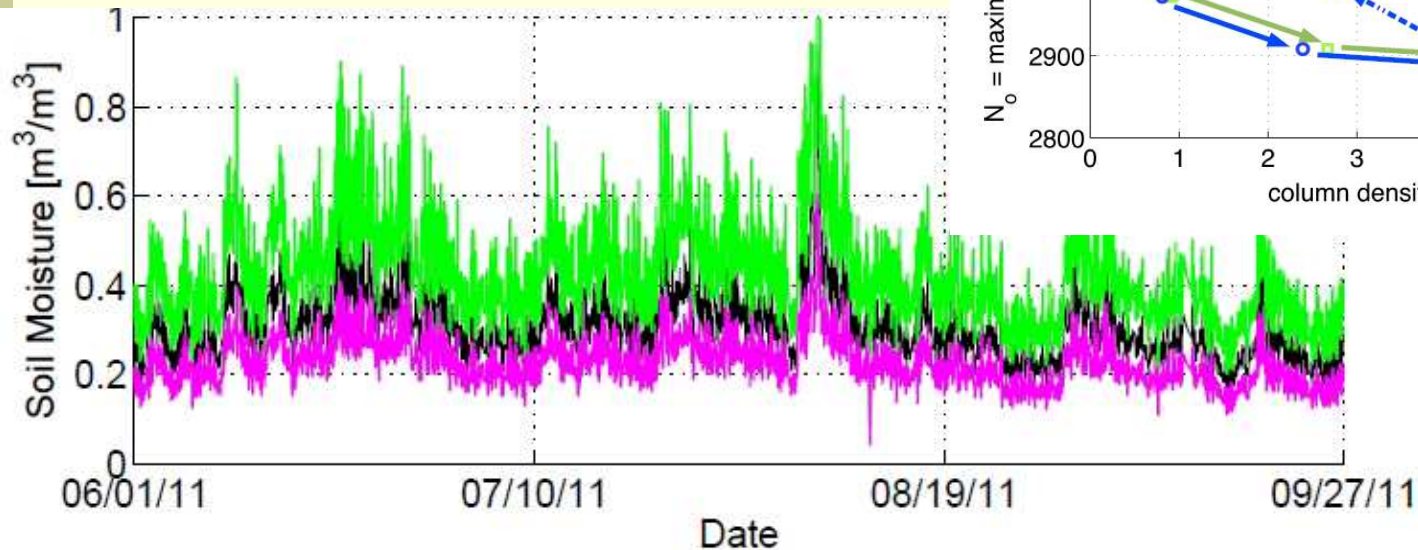
The role of biomass

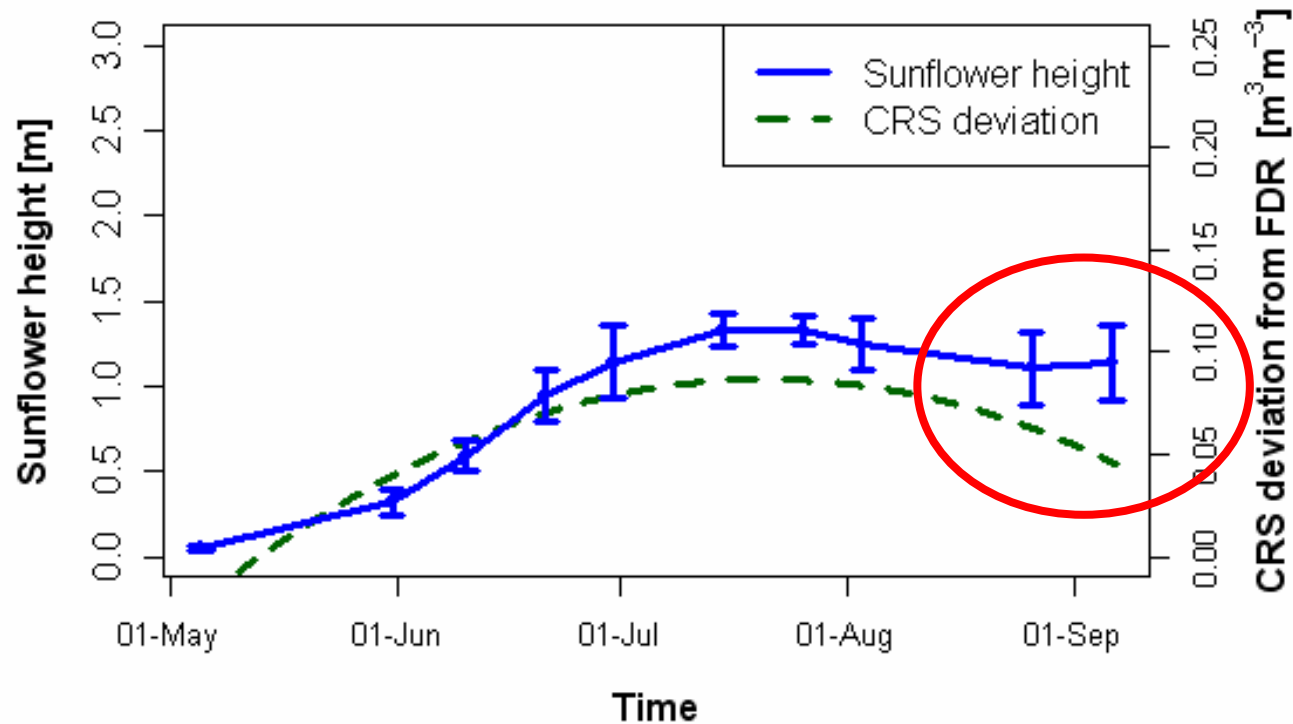Hornbuckle et al. (2012)

$$H_{\theta_v} = f(N, p(t))$$
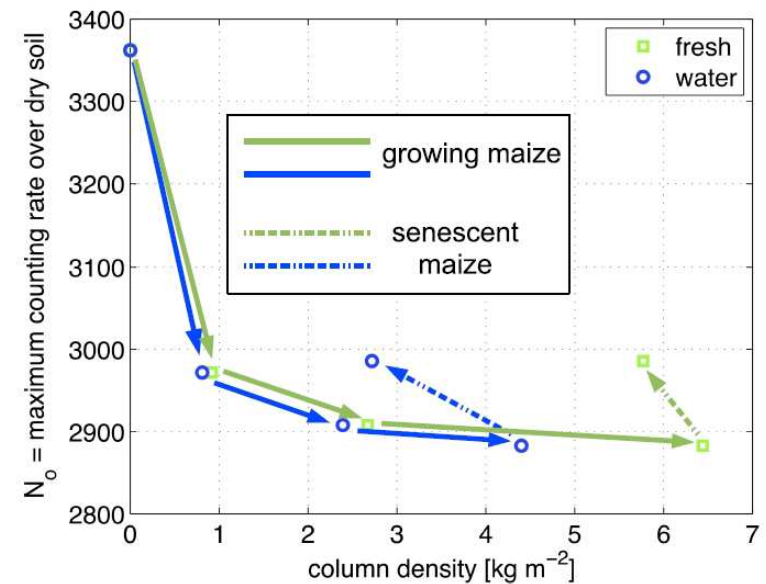
(1) $\quad H_{\theta_v} = f(N, p(t))$

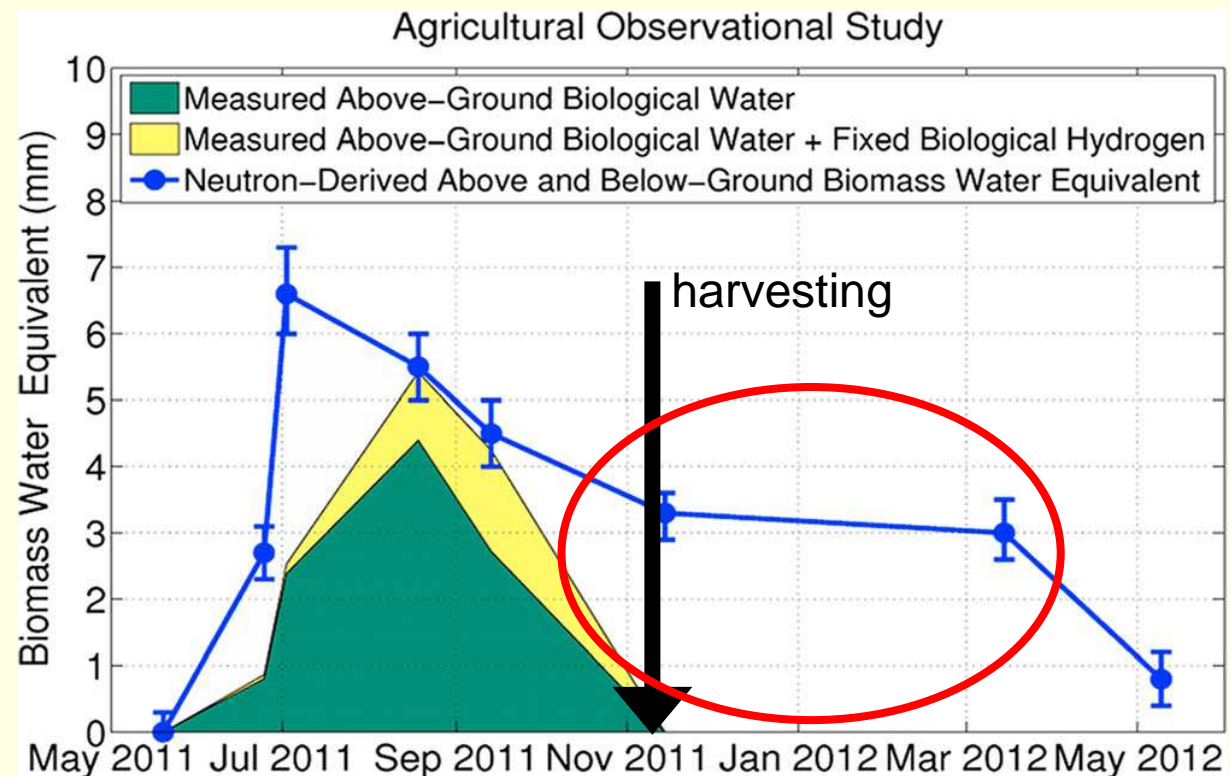(2) $\quad H_{\theta_v} = f(N, p) - \sum_{1}^{k} H_i(t)$

To develop an approach to correct the signal for multiple time-varying hydrogen pool (e.g., biomass)

■ Correlation with height crop or LAI

- Even more complicate when we saw the results in Franz et al. (2013)

$$(1) \quad H_{\theta_v} = f(N, p(t))$$

$$(2) \quad H_{\theta_v} = f(N, p) - \sum_{1}^{k} H_i(t)$$

➡ To develop an approach to correct the signal for multiple time-varying hydrogen pool (e.g., biomass)
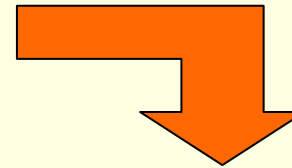
➡ related also to below ground biomass

The assumptions…

(1) Static hydrogen pool can be intrinsic considered in the local calibration

$$\theta_{CRS} = \left(\frac{a_0}{\frac{N}{N_o} - a_1} - a_2 \right) \cdot \frac{\rho_b}{\rho_w}$$

Desilet et al. (2010)

In case more than one time-varying H pool

$$\theta_{CRS} = \theta_{CRS\ c} \pm \theta_{bio}$$

$$BWE = \left(\theta_{CRS} - \theta_{CRSc} \right) \cdot z \cdot 10$$

$$\theta_{CRS} = \theta_{CRS_c} \pm \theta_{bio}$$
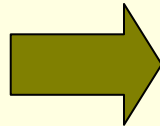
sampling campaign θ_{sam}

$$\theta_{CRSc} = \theta_{sam}$$

snapshot in time

network $\theta_{SoilNet}$

$$\theta_{CRSc} = \theta_{SoilNet}$$
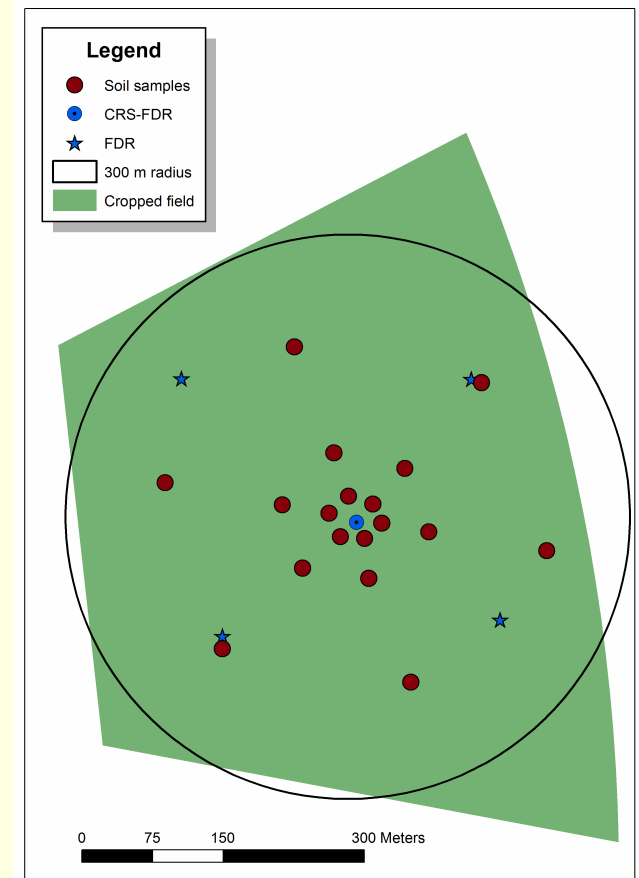
Installation??

Can we do something more?

A scaling approach

$$\theta_{CRSc} = m_i \cdot \theta_i + c_i$$

Soil moisture in one position within the field

2013 Maize
Cosmic-Ray probe
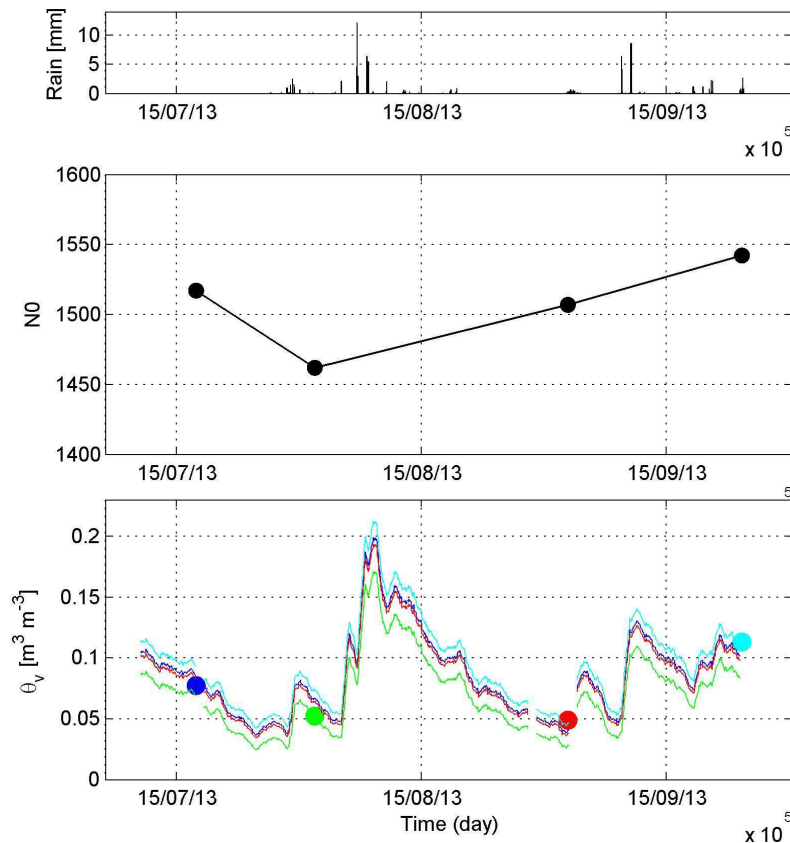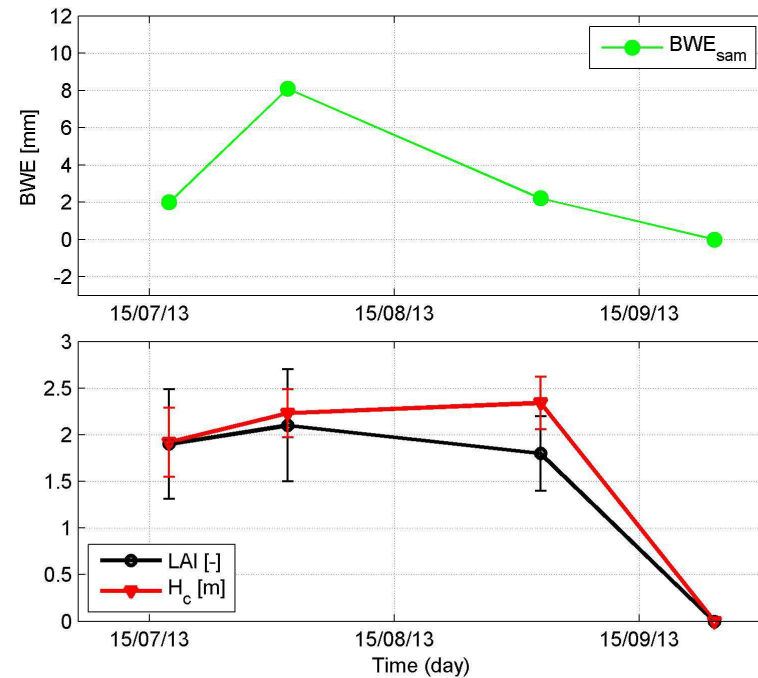FDR probes
4 soil sampling campaigns

Legend
● Soil samples
● CRS-FDR
★ FDR
□ 300 m radius
▮ Cropped field

0   75   150   300 Meters

$$BWE = \left(\theta_{CRS_{(4)}} - \theta_{sam} \right) \cdot z \cdot 10$$

A scaling approach

$$\theta_{CRSc} = m_i \cdot \theta_i + c_i$$

RMSE from 2.2% to 1.5%

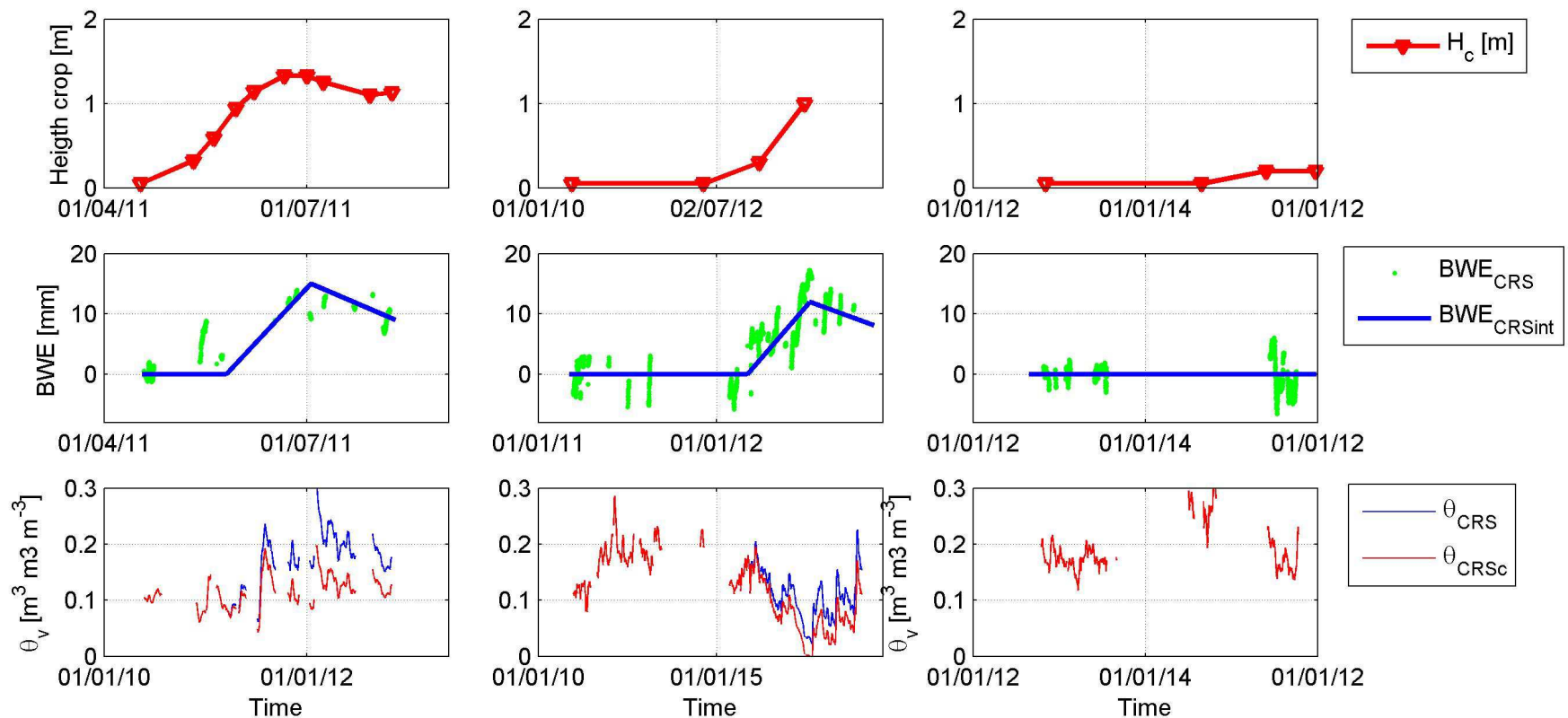$Y = -0.7316x + 0.1792$
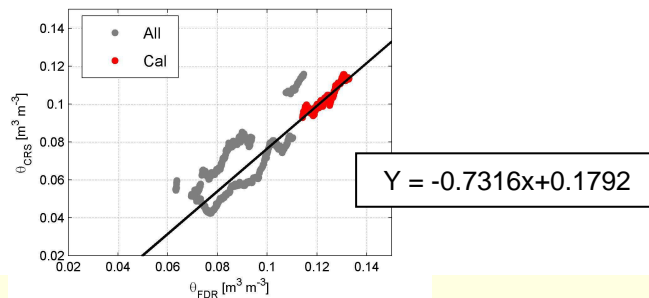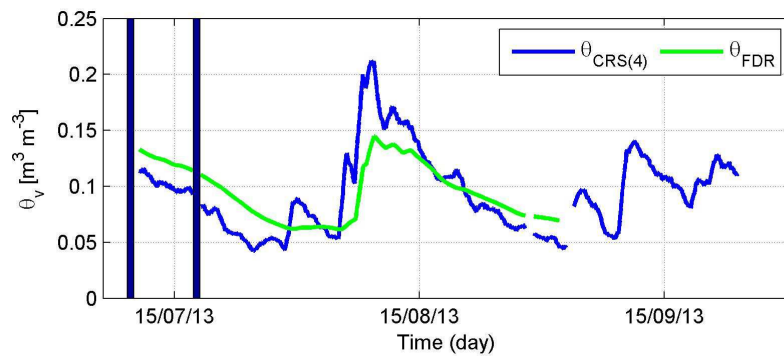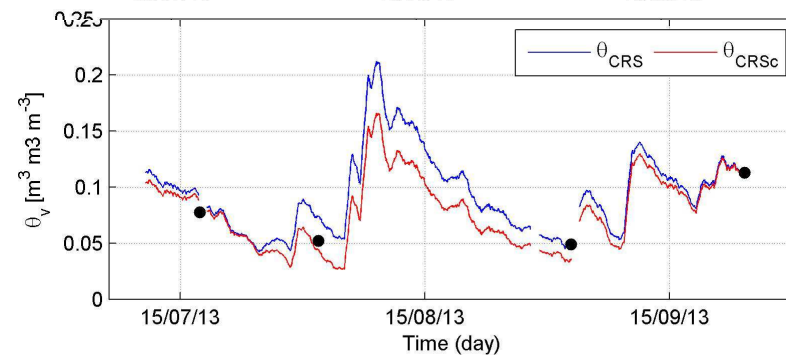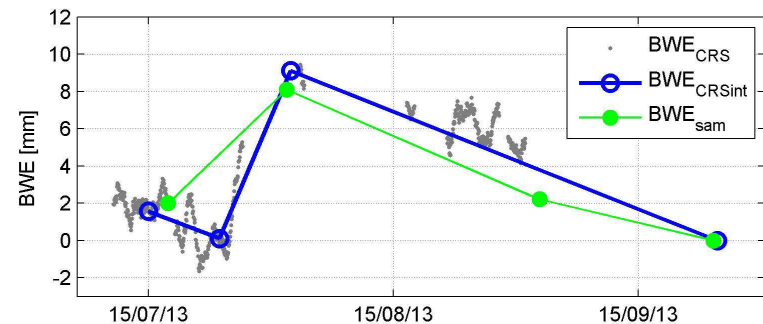
Experimental site (Bornim)
Data from 2011 in different crop conditions

Scaling approach in a longer term application

Conclusions

- Application of Cosmic ray neutron sensing for soil moisture in cropped field
    - Challenges due to multiple time-varying hydrogen pools

- Scaling soil moisture
    - Practicable and reliable method to account for biomass correction
    - Opportunity for upscale and downscale soil moisture
    - Attention: empirical approach!

    - Paper in prep.

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R.Gebbers

Thank you for the attention
Questions and comments