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AgSystems

Cover crops vs. fallow: water, nitrogen and salinity integrated for a more sustainable irrigated system

Miguel Quemada and JL Gabiel
Department of Crop Ecology and Production
Technical University of Madrid

Introduction

Strategies for increasing N efficiency in irrigated systems

- Adjust N fertilization to crop needs
- Link between N and water management
  - Irrigation: excessive vs. adjusted
  - Fertigation

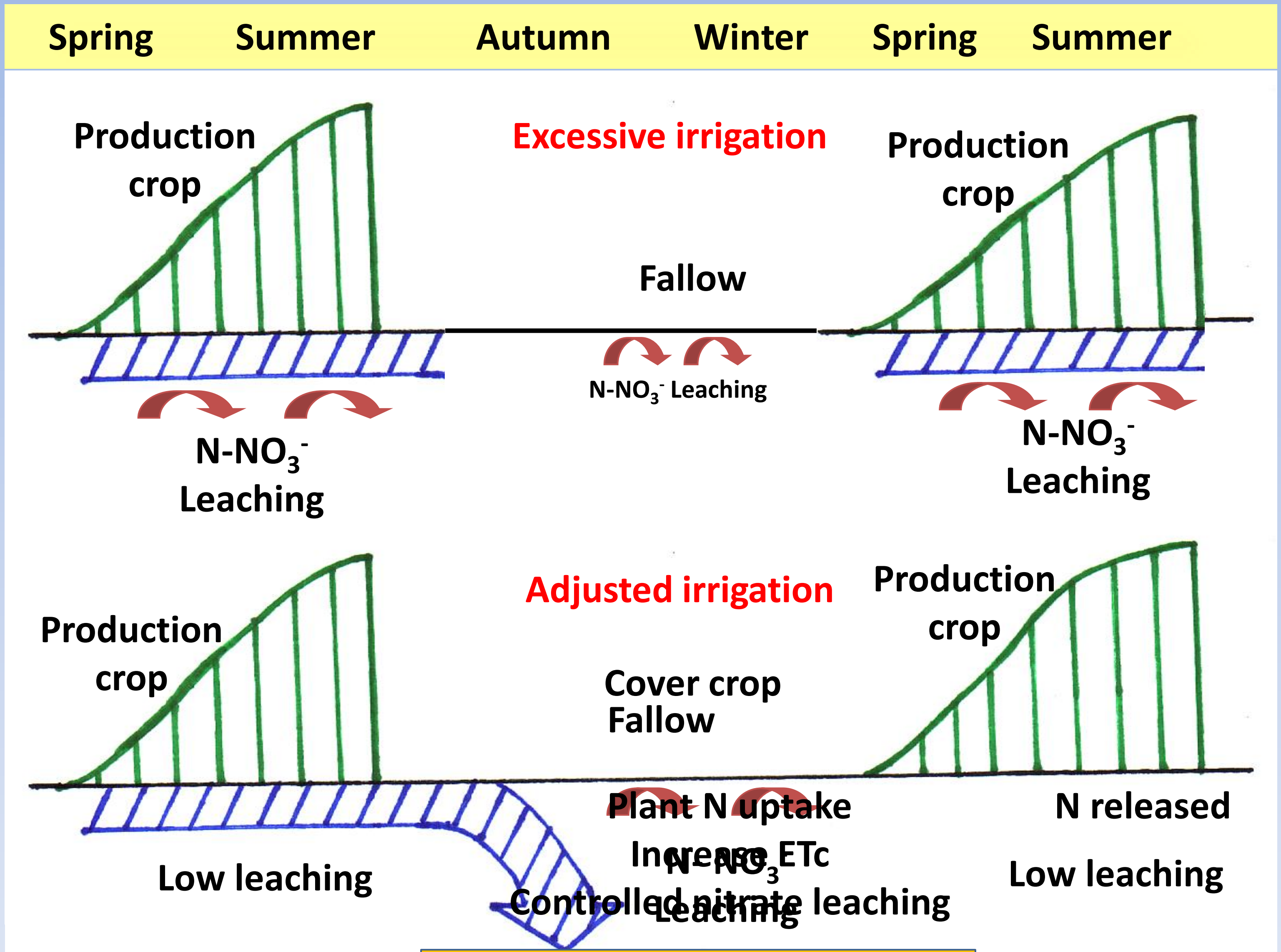
Replacing fallows with cover crops

- Rotation: high N requirement/low N requirement crops

Irrigated land in Spain

Irrigated land	World	Spain
Cropland surface	16%	17%
Agricultural production	39%	>60%

Introduction



Do salts accumulate in the soil?

Introduction

Soil salinity and salt leaching

- Soil salinity ≈ salt accumulation in the soil profile

  May cause yield reduction

  land degradation

  Area affected in the world > 80 millions ha (FAOSTAT, 2012)

- Salt leaching → diffuse pollution by return flows

  Yield reduction in irrigated land

  Effect on aquatic fauna and vegetation

  Industrial processes

Objective

To study the effect of replacing fallow with winter cover crops in an intensive maize production systems.

In this presentation, we’ll focus on the effect on:

-water balance and nitrate leaching

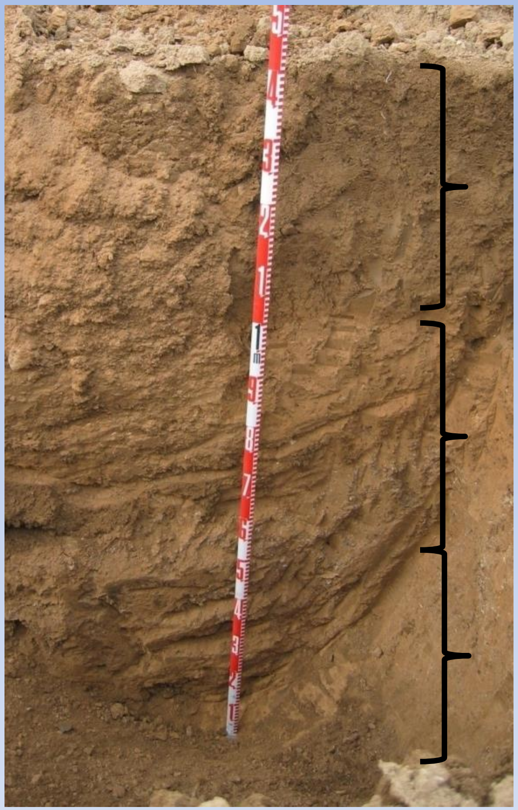
- salt leaching and salinity

Material and methods

- **Farm “La Chimenea”** **Location: Aranjuez, Vegas río Tajo**
- **Climate:** Dry Mediterranean, monoxeric (June-Septembre)
  - Mean temperature: 20.5 ºC, maximum , and 6.5 ºC minimum
  - Mean rainfall: 400 mm
  - ETo=753 mm

Material and methods

Soil characteristics



Depth cm	pH (1:2.5)	EC dS/m	Organic C g/kg	CO_3 g $CO_3^{=}$/kg	Texture
0-23	8.1	0.31	18.5	198	Silty clay loam
23-40	8.1	0.45	17.0	201	Silty clay loam
40-70	8.0	0.90	12.7	159	Clay loam
70-120	7.8	2.10	13.0	181	Loam

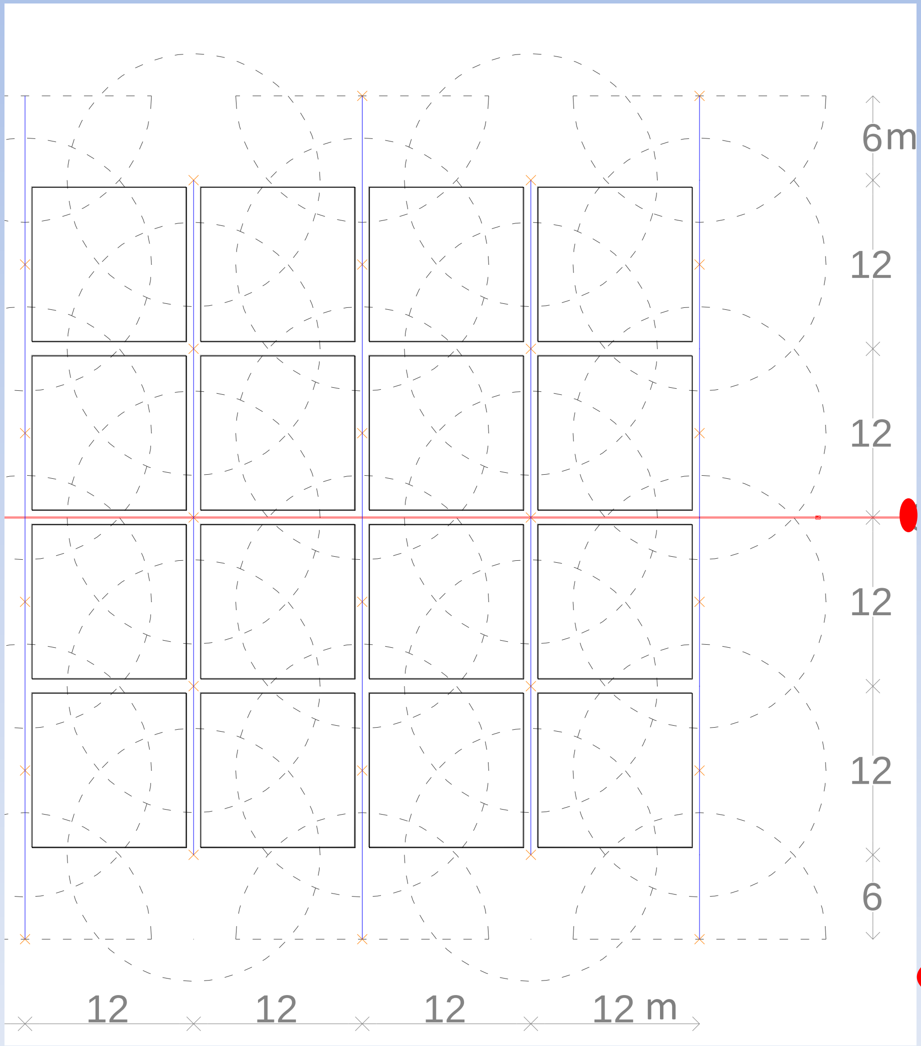
pH ~ 8
High to medium organic C and carbonates
Texture: Silty clay loam
Low salinity in the upper layers

Classification

- **Typic calcixerept** (Soil Survey Staff, 2003)
- **Calcisol háplico** (FAO-UNESCO, 1988)

Material and methods

Experimental design



-Sprinkle irrigation (12x12 m)

- Main crop: maize cycle 700

- N fertilizer application (NH_4NO_3):

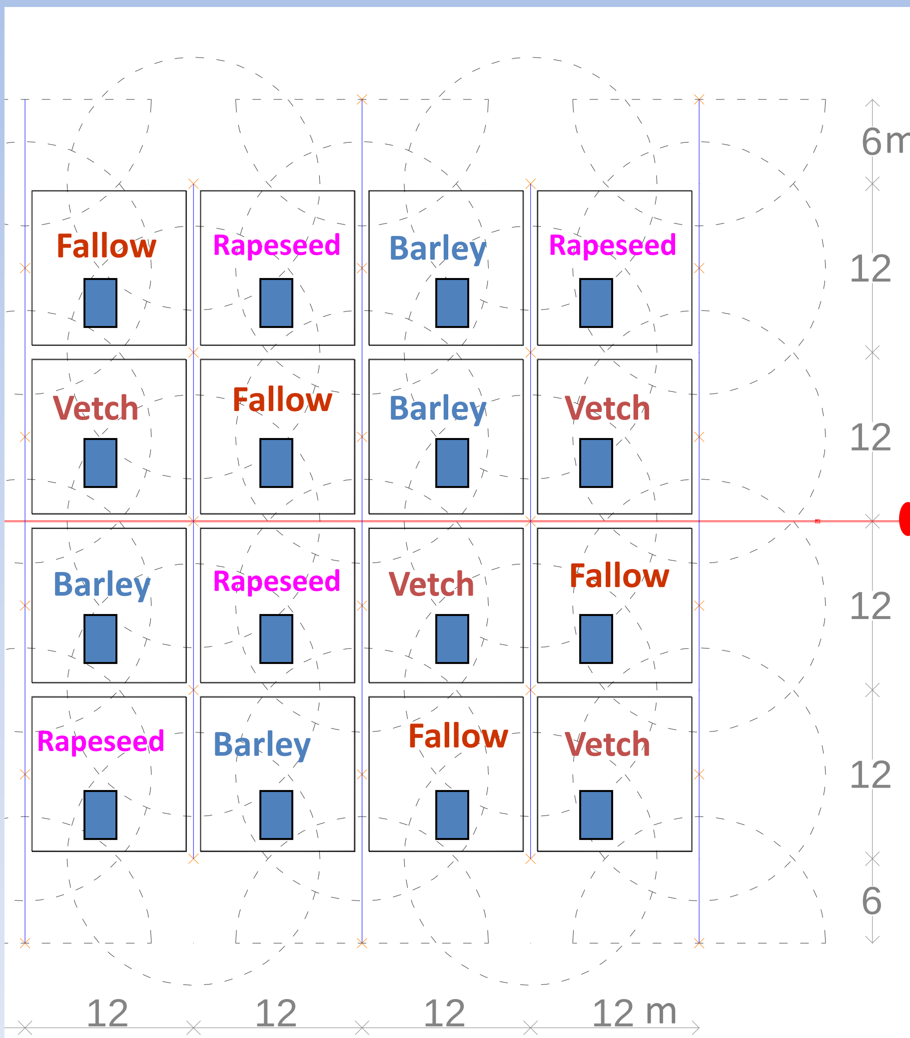
V4: 140 kg N ha^{-1}

V8: 70 kg N ha^{-1}

(mm)	2007	2008	2009
ETc	643.7	624.9	716.1
Irrigation	575.7	533.7	656.4
Rain	106.6	142.0	45.4
Total water input	682.3	675.7	701.8
Total water input/ETc	1.06	1.08	0.98

Material and methods

Experimental design



- Factorial: 4 factors x 4 reps
- Factors: 3 cover crops
  bare soil

Cover crop	Cultivar	Sowing rate
Barley	Clarine	180 kg ha^{-1}
Vetch	Vereda	140 kg ha^{-1}
Rapeseed	Licapo	6 kg ha^{-1}

Maize: April → October

Cover crops: October → March

N^{15} Microplots (2 x 1.25 m^2)

Labeled $^{15}NH_4{}^{15}NO_3$ (2.5 atom % ^{15}N)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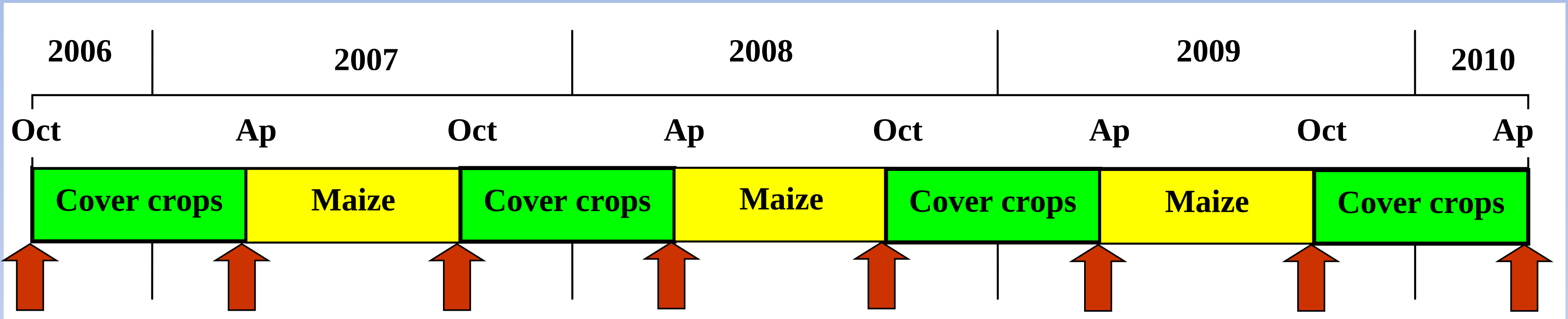
Material and methods

Experimental procedure and measurements



Soil NMIN$_{1.2\ m}$: KCl extracts in 0.20 m intervals ($NH_4^+ + NO_3^-$)

Soil salt accumulation$_{1.2\ m}$: EC in saturated paste extracts in 0.20 m intervals ($S\ m^{-1}$)

Crop parameters: Biomass, Yield, Plant N and C concentration

^{15}N by mass spectrometry: plant and soil samples from microplots

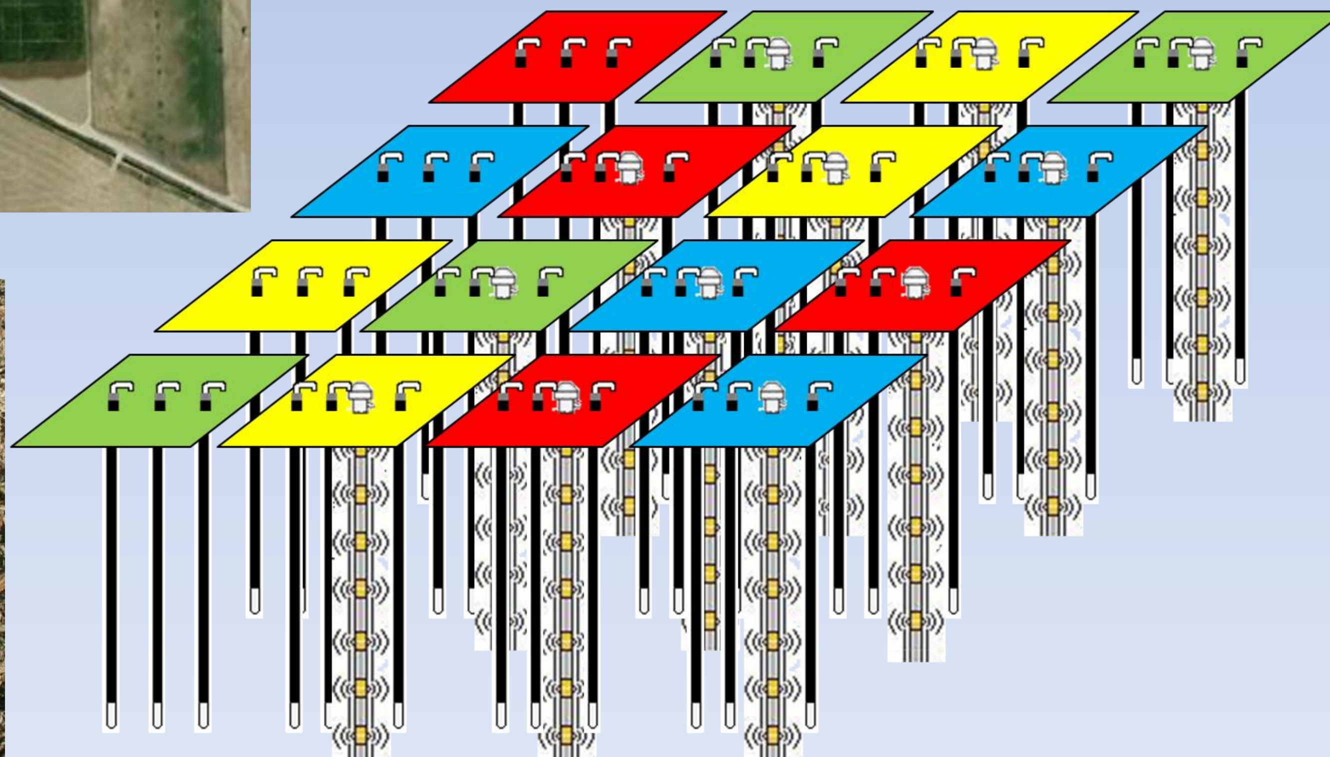
Soil parameters: Water content at saturation and fiel capacity, saturated hydraulic conductivity, bulk density

Crop parameters: Leaf area index, Kc, active root depth

Soil water content (SWC$_{1.2\ m}$): FDR in 0.20 m intervals down to 1.3 m

Soil solution in ceramic cups at 1.2 m: determination of [NO_3^-] and EC

Material and methods



Material and methods

Calculations

-**Water balance :** obtained by inverse calibration of the numerical model WAVE (Vanclooster et al. 1996) with soil water data collected daily with FDR sensors.

Outputs: Crop evapotranspiration (ETc)

Water percolation below root zone (= Drainage)

Runoff (negligible)

- **Nitrate leaching:**

soil solution sampling intervals: $N\text{-}NO_3^-$ leached = Drainage x $[N\text{-}NO_3^-]_{\text{soil solution 1.3 m}}$

Cumulative nitrate leaching = Σ (nitrate leaching intervals)

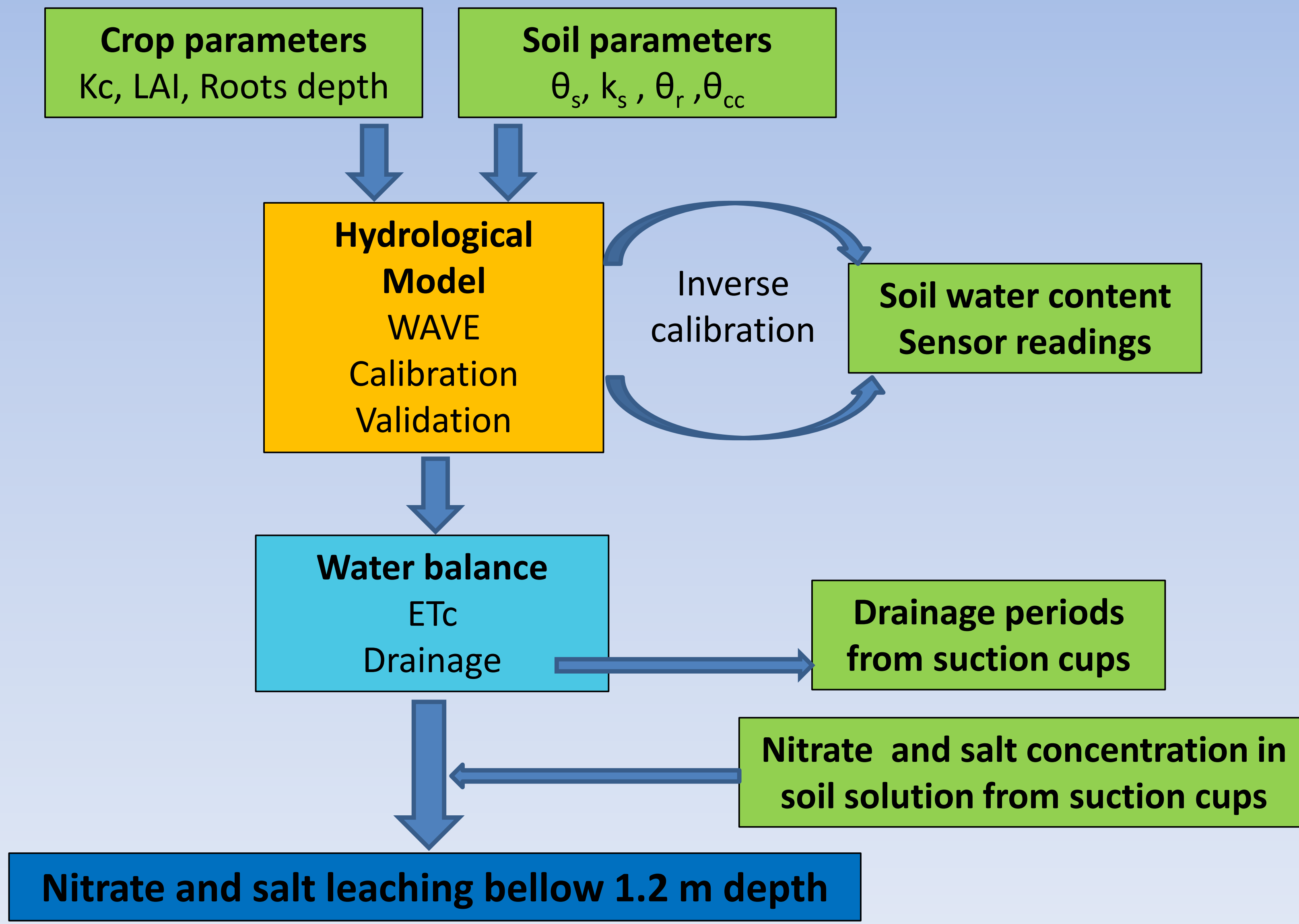
- **Salt leaching:**

soil solution sampling intervals: Salts leached = Drainage x $[\text{Salts}]_{\text{soil solution 1.3 m}}$

Cumulative salt leaching = Σ (soil solution sampling intervals)

Material and methods

Water balance



Results

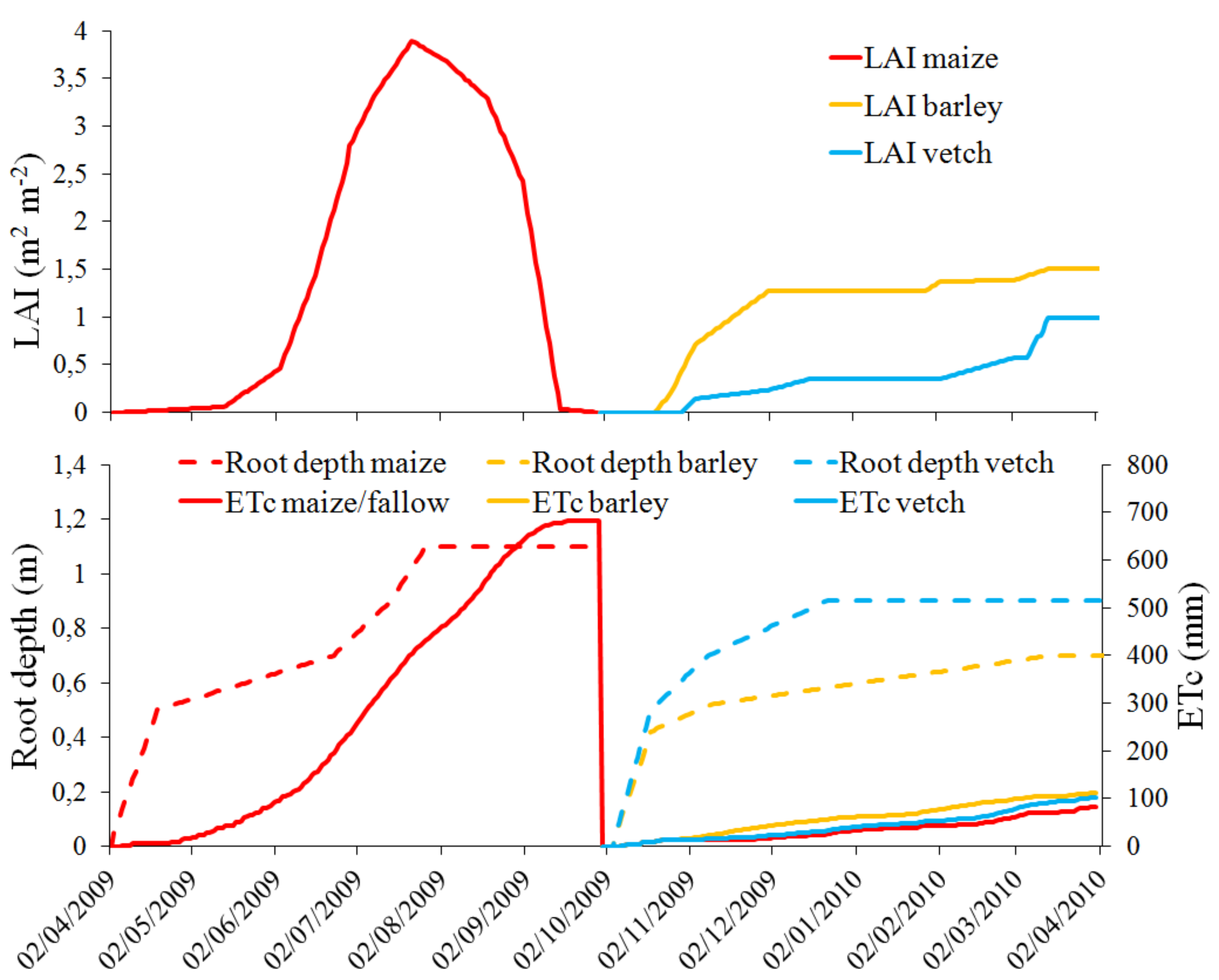
-crop productivity and N uptake by CC and maize

-**water balance and nitrate leaching**

- **salt leaching and salinity**

Results

Crop parameters evolution: LAI, Kc and effective rooting depth



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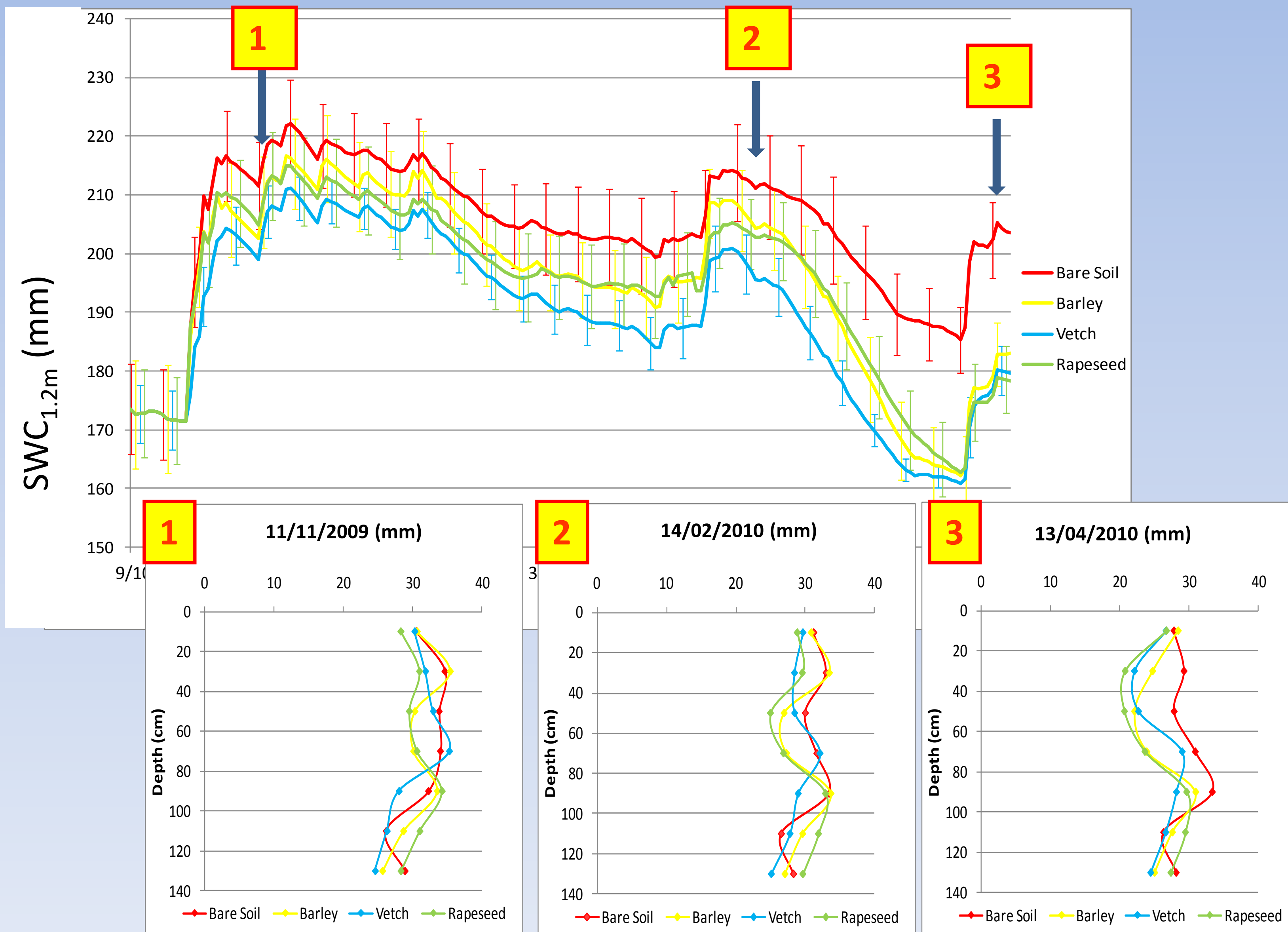
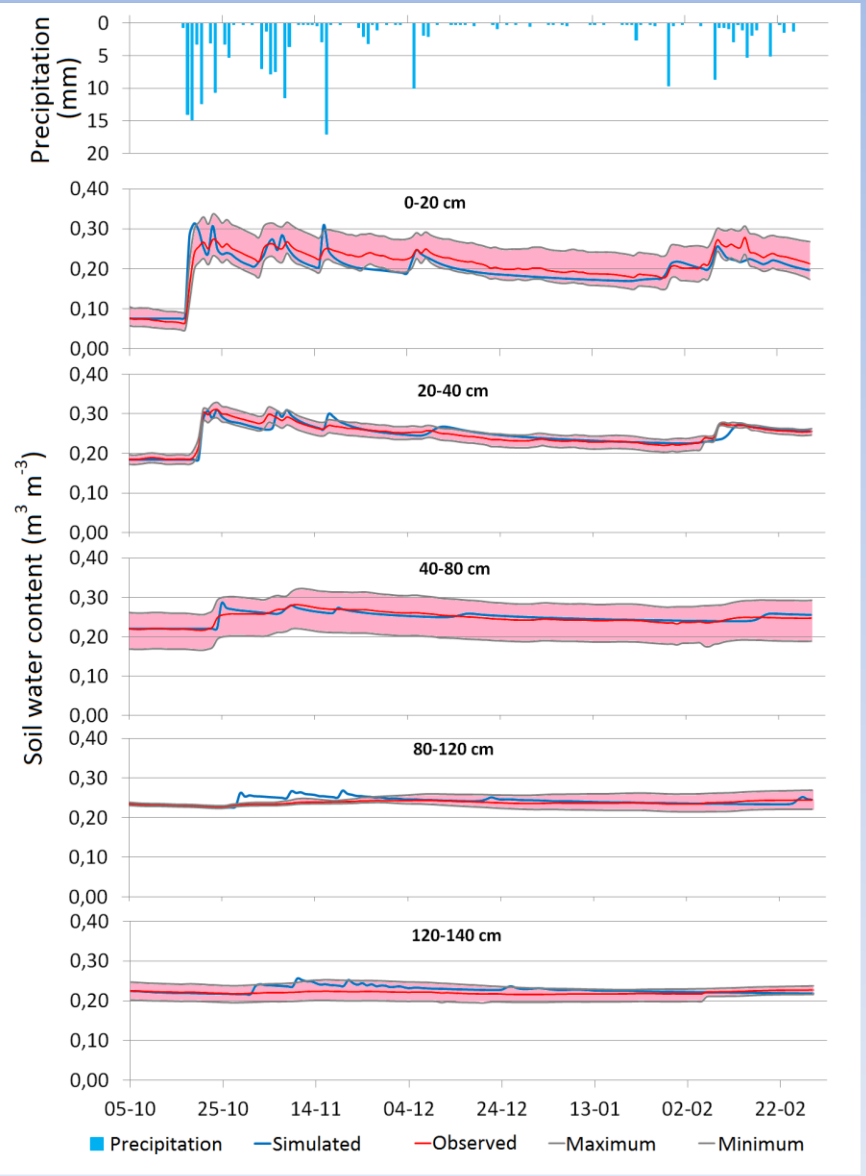
Results

Soil water content   Cover crops period   2009-2010



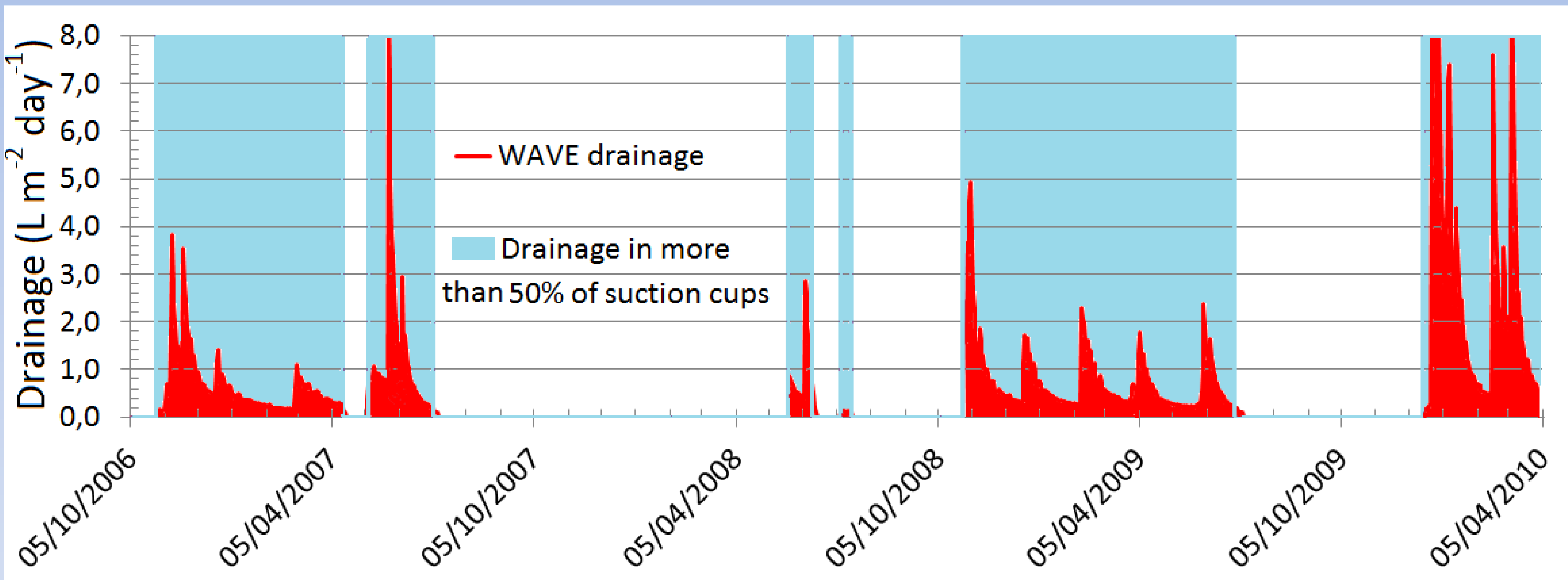
Results

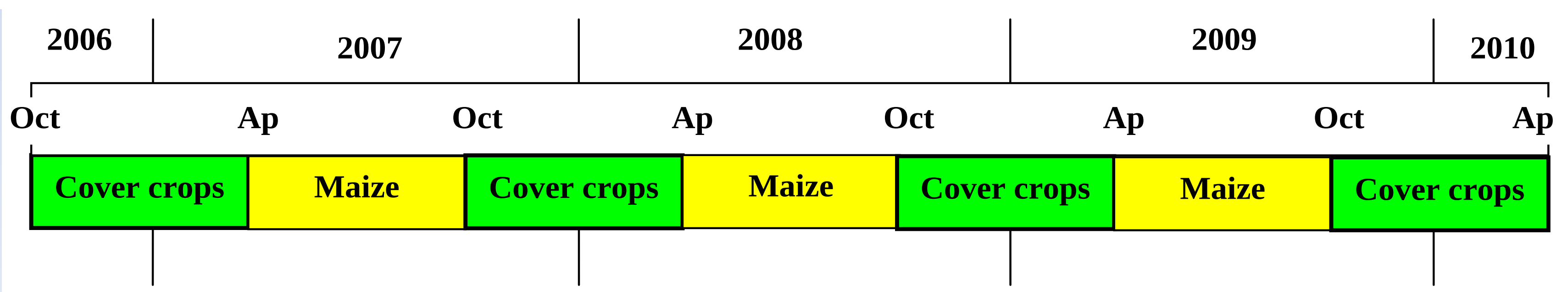
Validation WAVE model (C_{ef} = 0.89; RMSE = 6.7 mm)



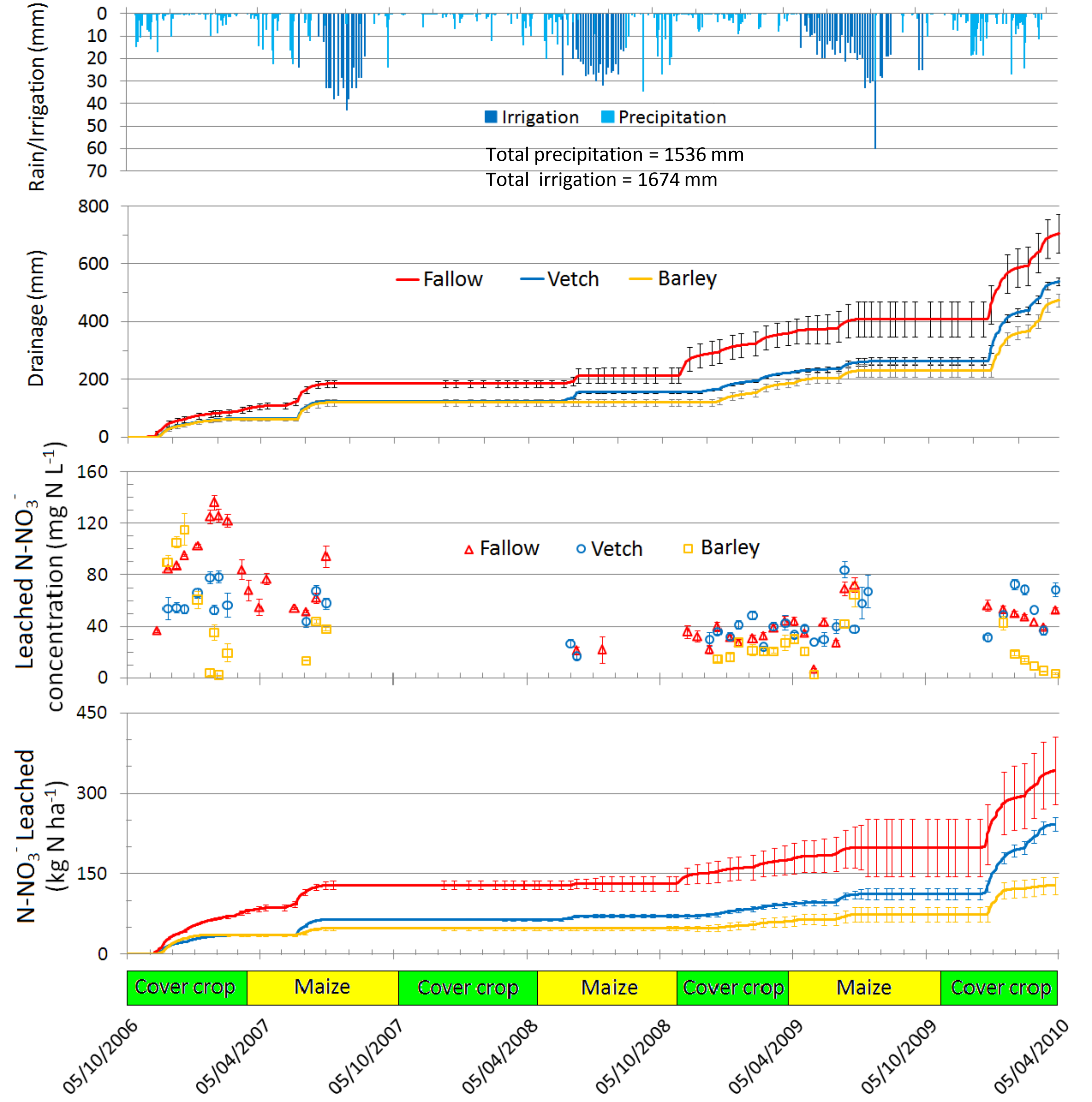
Results

Drainage periods simulated ~ Drainage periods based on suction cups soil solution present > 50%





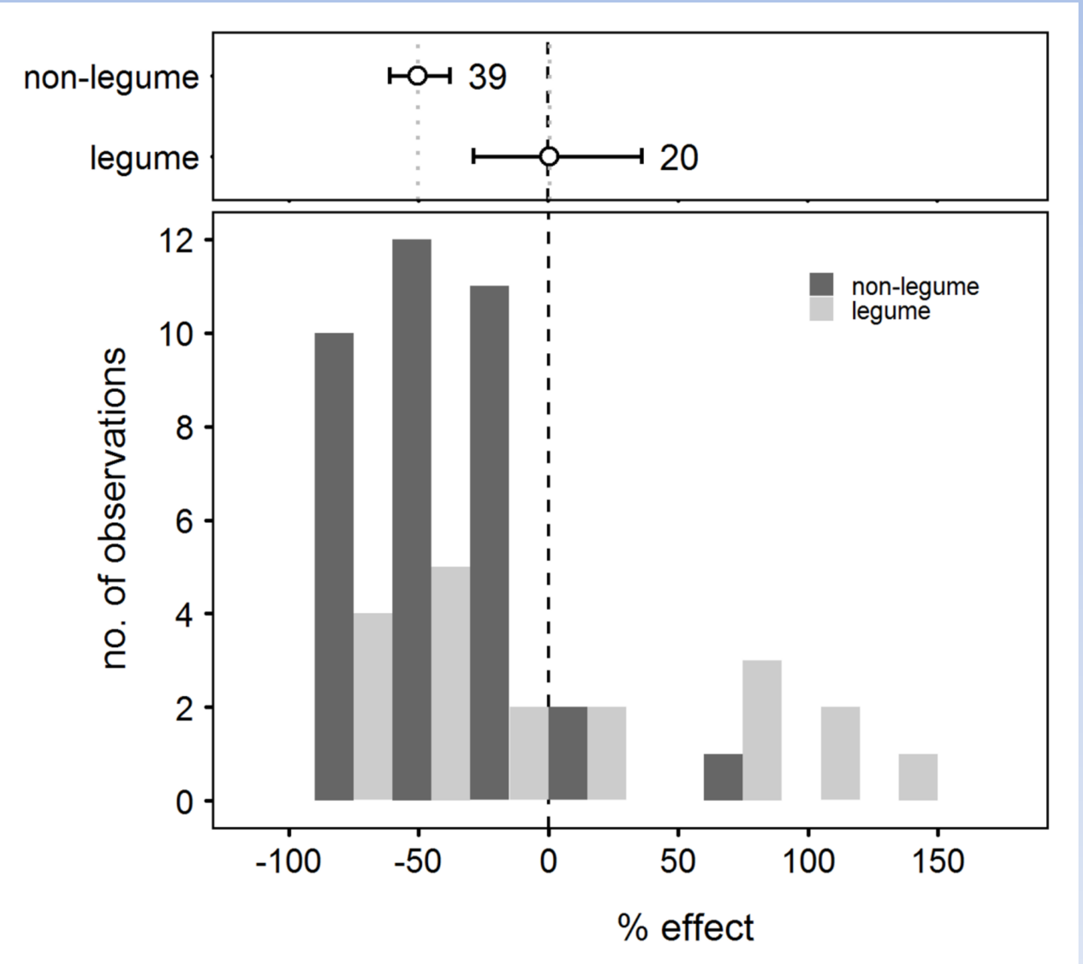
Results: Drainage and nitrate leaching



Agriculture Ecosystems & Environment (2012) 155:50-61

Results

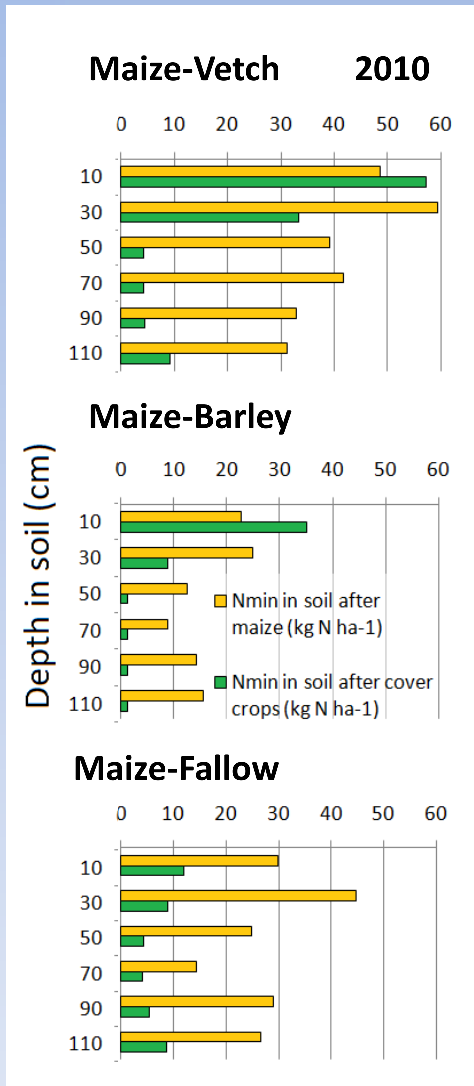
-Mean effect of CC on controlling nitrate leaching with respect to the fallow. Meta-analysis from 59 observations



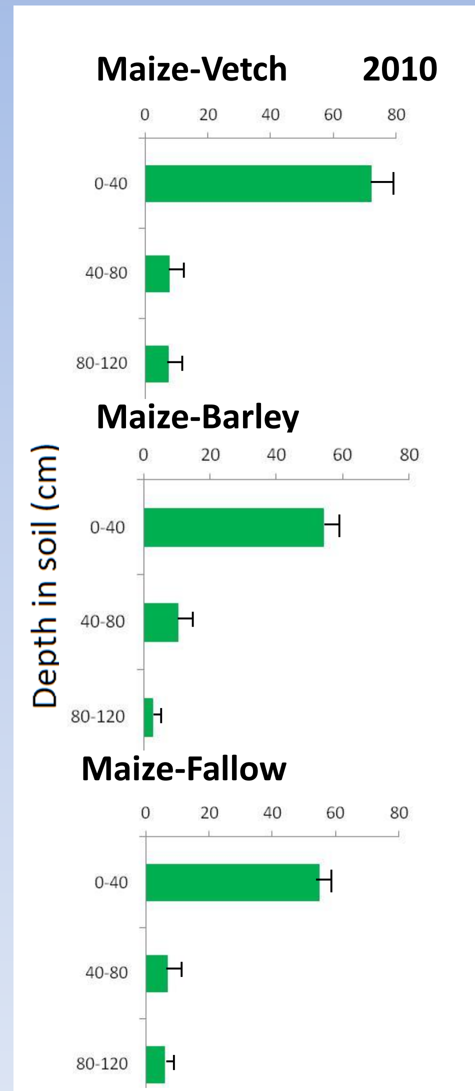
Agriculture Ecosystems & Environment (2013) 174:1-10

Results: Soil N accumulation

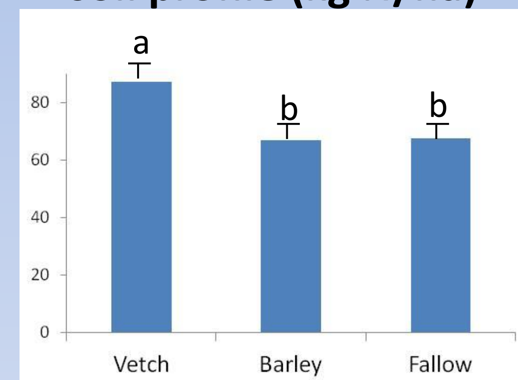
Soil mineral N accumulation



^{15}N recovered in the soil after CC treatment



^{15}N recovered in the soil profile (kg N/ha)



European Journal of Agronomy (2011) 34: 133-143
Agriculture Ecosystems & Environment (2012) 155:50-61

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Results: Salt leaching

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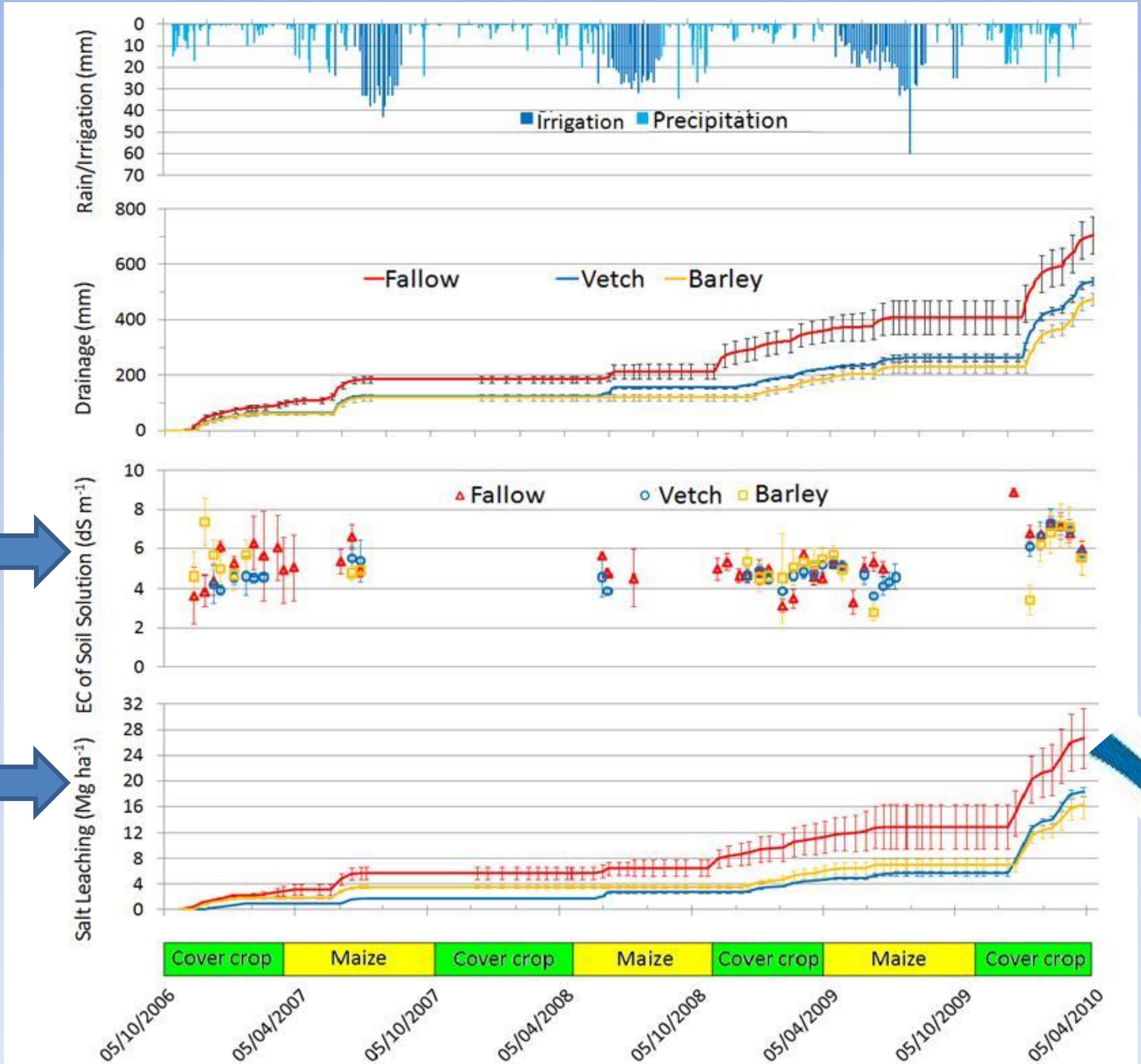
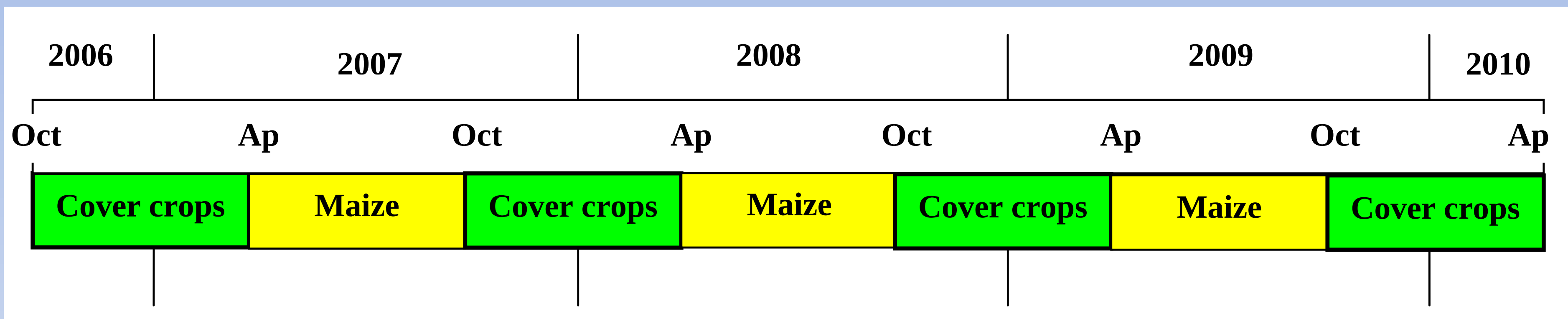


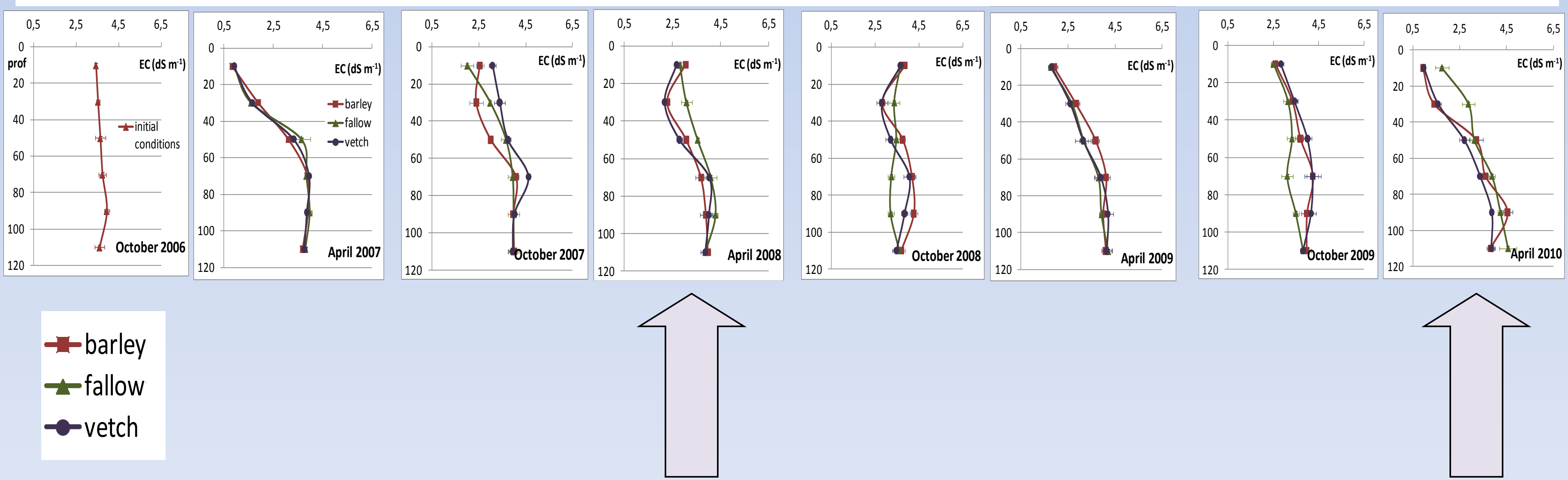
Do salts accumulate in the soil after the CC?

Agriculture Ecosystems & Environment (2012) 158: 200-207

Results: Soil salt accumulation

Salt distribution in the soil profile



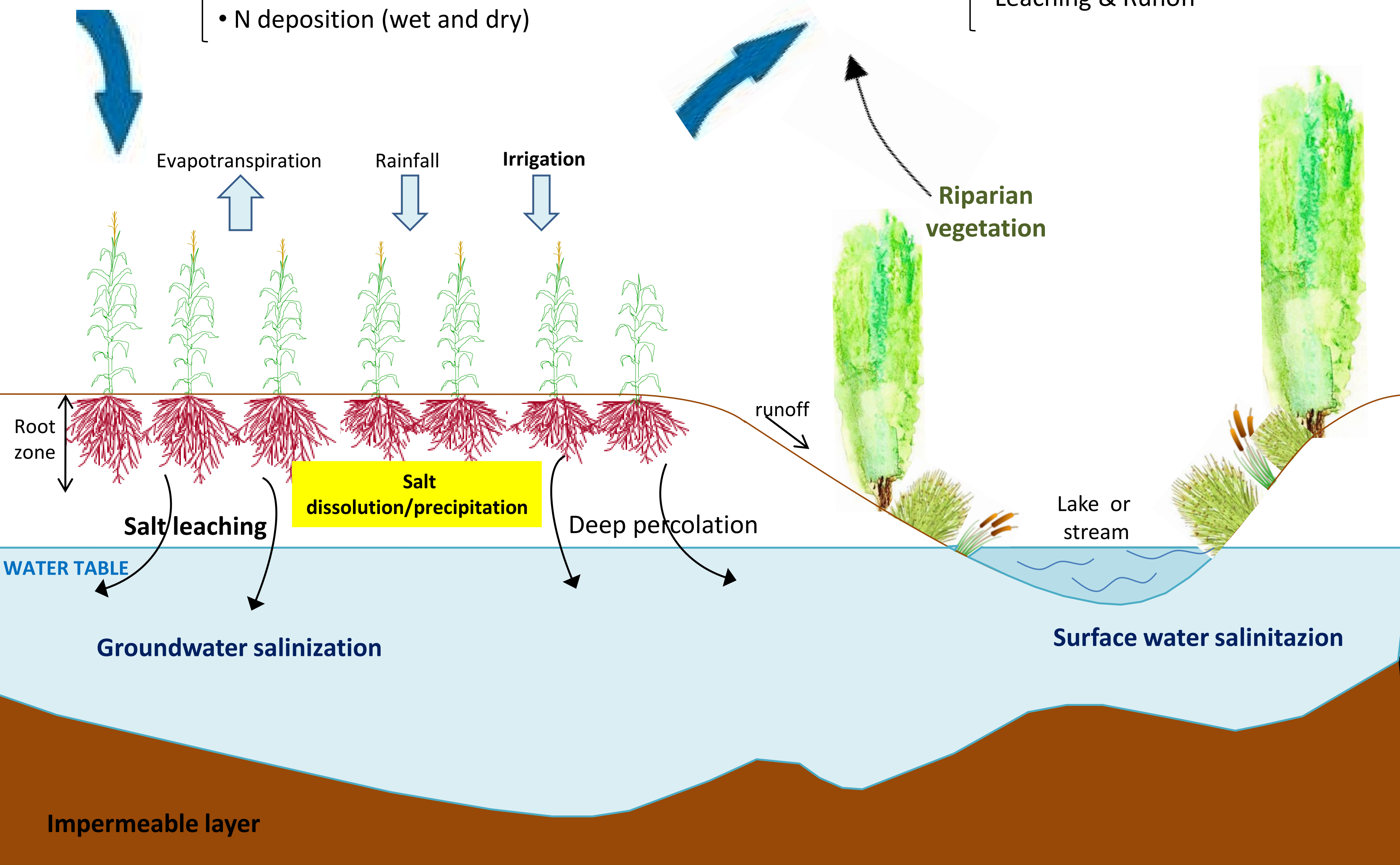


Agriculture Ecosystems & Environment (2012) 158: 200-207

Salts in irrigated cropping systems

Salt inputs
- Fertilizer application (organic or inorganic)
- Irrigation water
- N deposition (wet and dry)

Salt outputs
- Plant N uptake/exported
- Leaching & Runoff



Conclusions

• The legume cover crop enhanced N retention and availability in the topsoil, reducing nitrate leaching with respect to the fallow and opening the option for further reduction in N fertilizer application.

• The barley was more efficient than the vetch at controlling the NO_3^- leaching, but keep lower soil mineral N content and may enhance pre-emptive competition with the subsequent cash crop.

• Cover crops reduced salt leaching without increasing salt accumulation in the soil, probably due to maintaining lower soil water content.

Journal of Irrigation and Drainage Engineering-ASCE (2014) 140 (9): A4014002
Agriculture Ecosystems & Environment (2012) 158: 200-207 and 155:50-61
European Journal of Agronomy (2011) 34: 133-143

THANK YOU FOR YOUR ATTENTION

http://www1.etsia.upm.es/GRUPOSINV/AgSystems

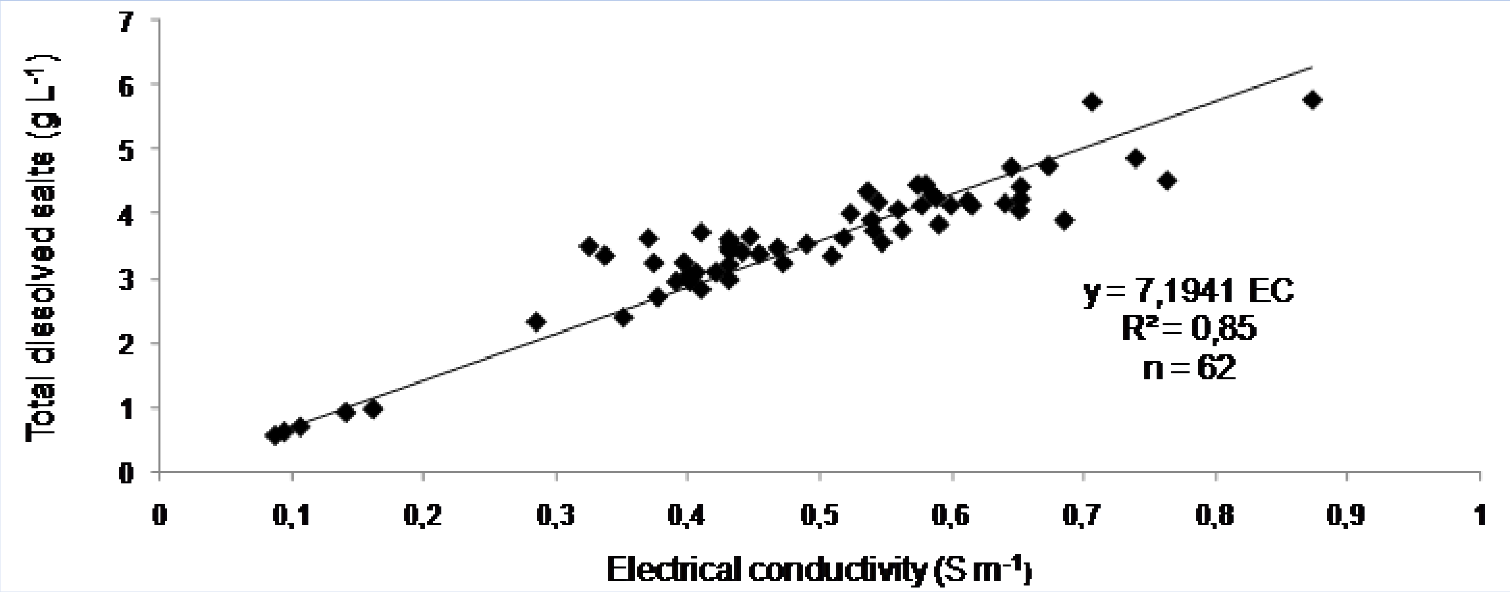
Material and methods

- **Calculations**

  - **Salt leaching:**

soil solution sampling intervals: Salts leached = Drainage x [Salt s]$_{\text{soil solution 1.3 m}}$

Cumulative salt leaching = Σ (soil solution sampling intervals)



TDS (g L^{-1}) = EC (S m^{-1}) * K

K = 5.5–9.0 (American Public Health Association, 1995)

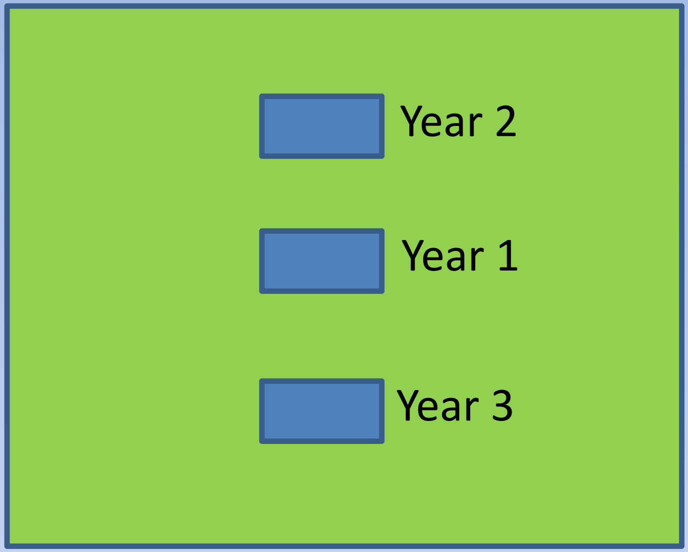
Material and methods

N^{15} Microplots (2 x 1.25 m^2)

Labeled $^{15}NH_4{}^{15}NO_3$ (2.5 atom % ^{15}N)

Two applications: V4: 140 kg N ha^{-1}

V8: 70 kg N ha^{-1}



$$\text{Crop } ^{15}\text{N recovery } (^{15}N_R) = N_{uptake} \frac{\{[^{15}N_{plant}] - [^{15}N_{nat.\,ab.}]\}}{\{[^{15}N_{fert}] - [^{15}N_{nat.\,ab.}]\}}$$

$$\text{N fertilizer efficiency (NRF)} = 100\ ^{15}N_R\,/\,^{15}N_{fert}$$

$$\text{N from other sources (NOS)} = \text{Crop } N_{uptake} - {}^{15}N_R$$

$$\text{Soil } ^{15}\text{N recovered} = N_{soil} \frac{\{[^{15}N_{soil}] - [^{15}N_{nat.\,ab.}]\}}{\{[^{15}N_{fert}] - [^{15}N_{nat.\,ab.}]\}}$$

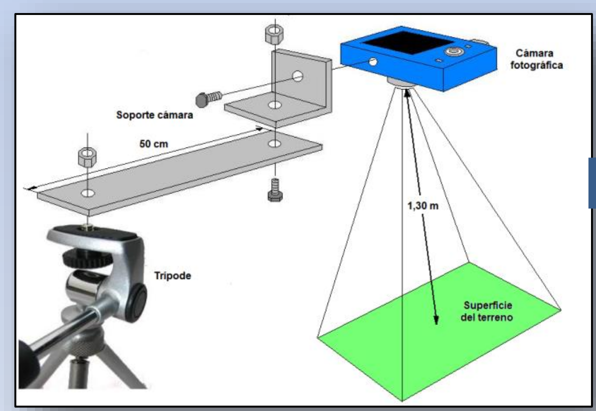
Material and methods

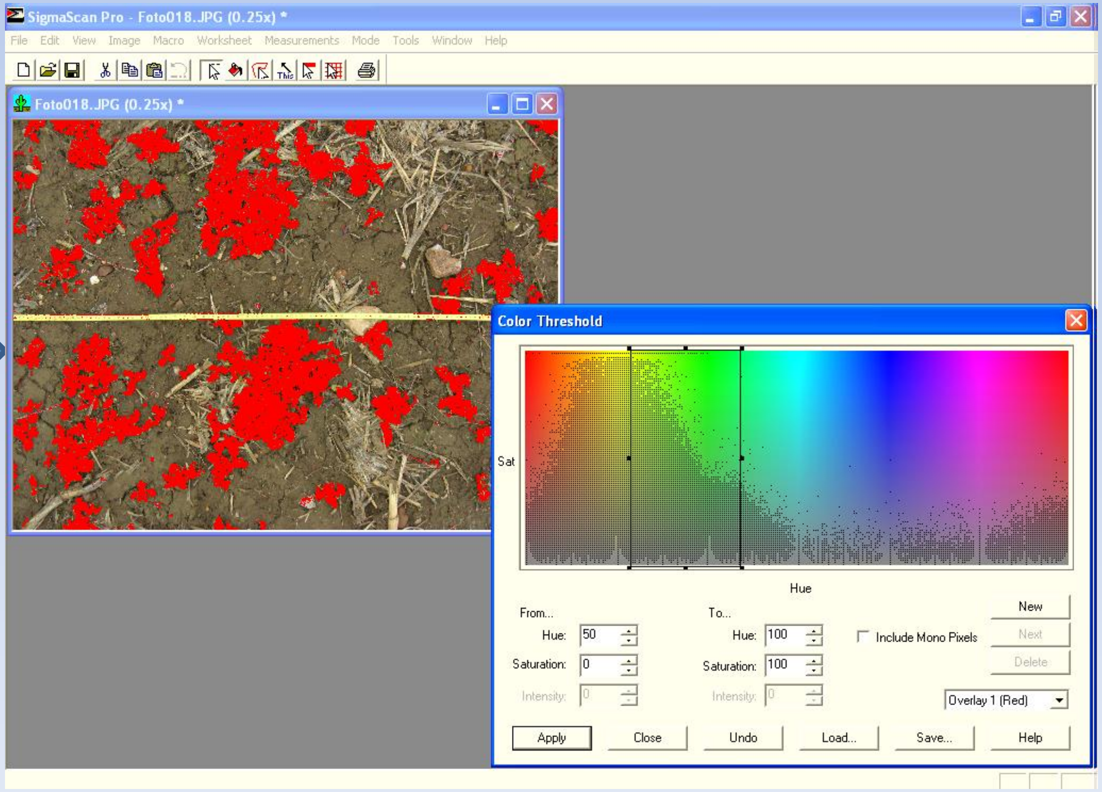
Direct estimation of crop parameters: Kc, LAI, effective rooting depth

Measurement of ground cover (GC) base on digital images analysis

GC → **Kc** FAO method (Allen et al., 1998)

GC → **LAI** estimated by (Ramírez et al., 2012)



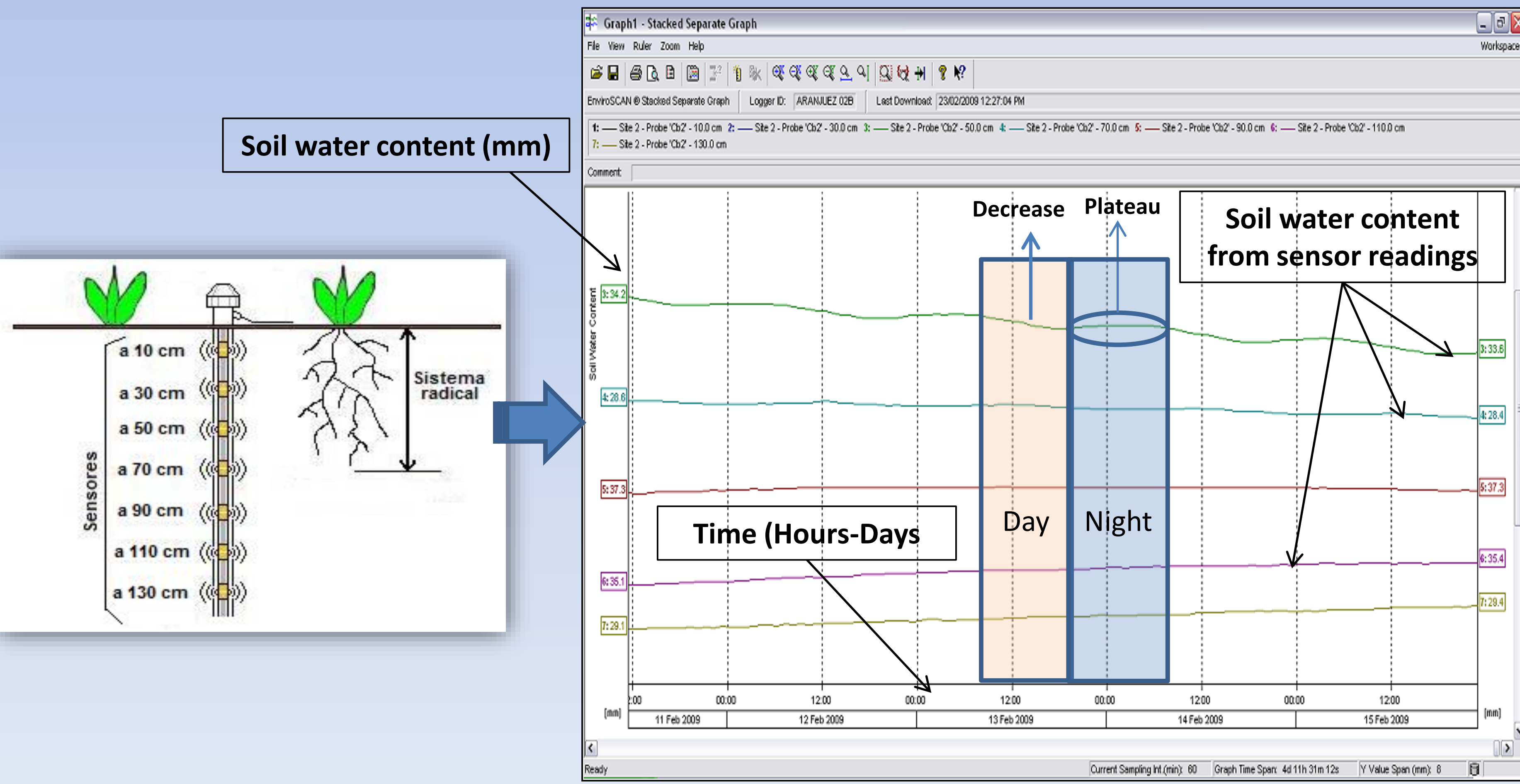


- Four images of 1 m^2 per plot
- Every other week

Material and methods

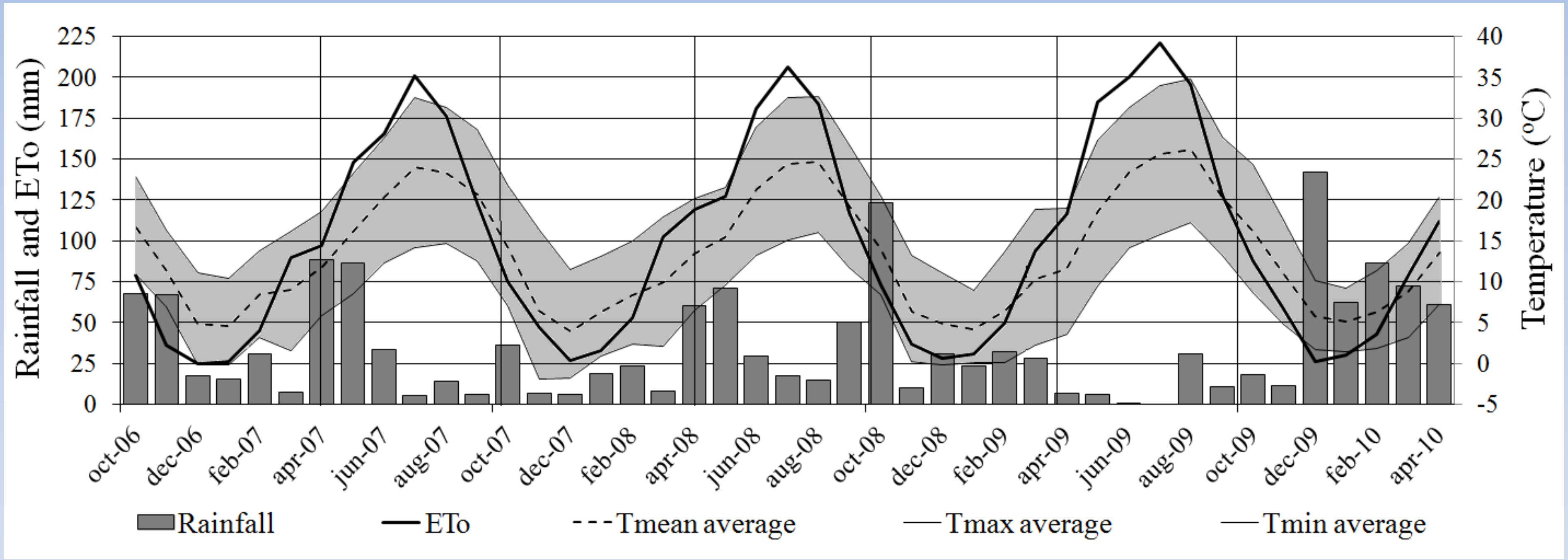
Direct estimation of crop parameters: Kc, LAI, effective rooting depth

Effective rooting depth



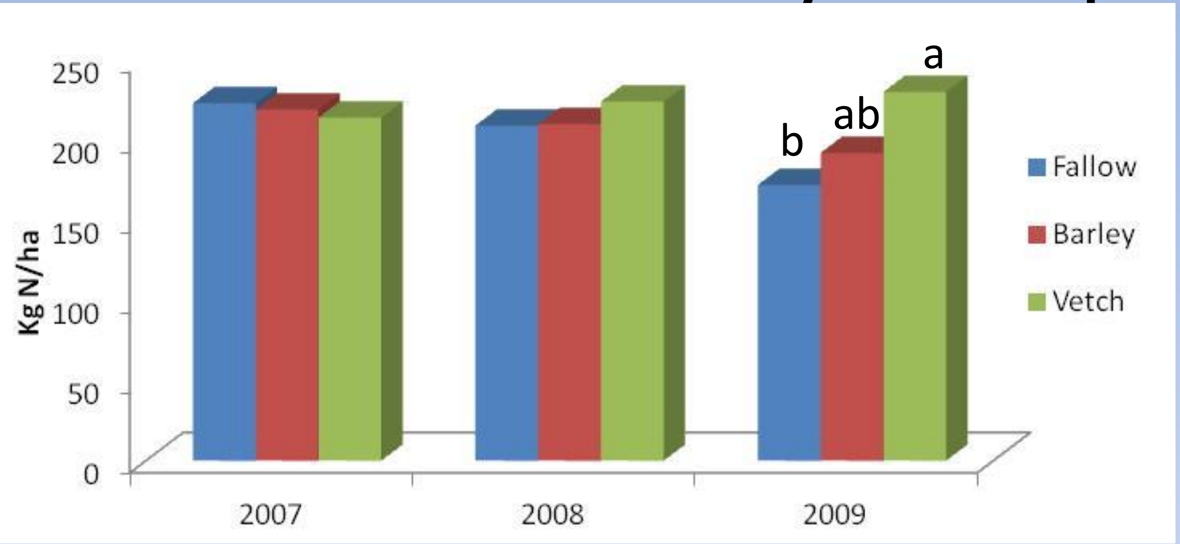
Results

Climatic data at the field experiment during the experimental period

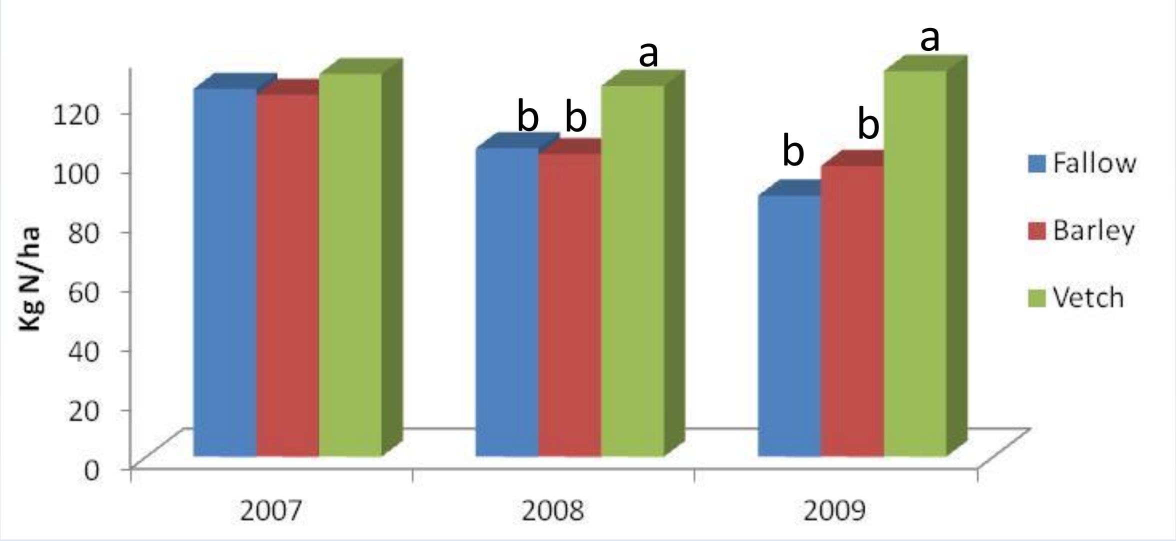


Results

Maize N content as affected by cover crops

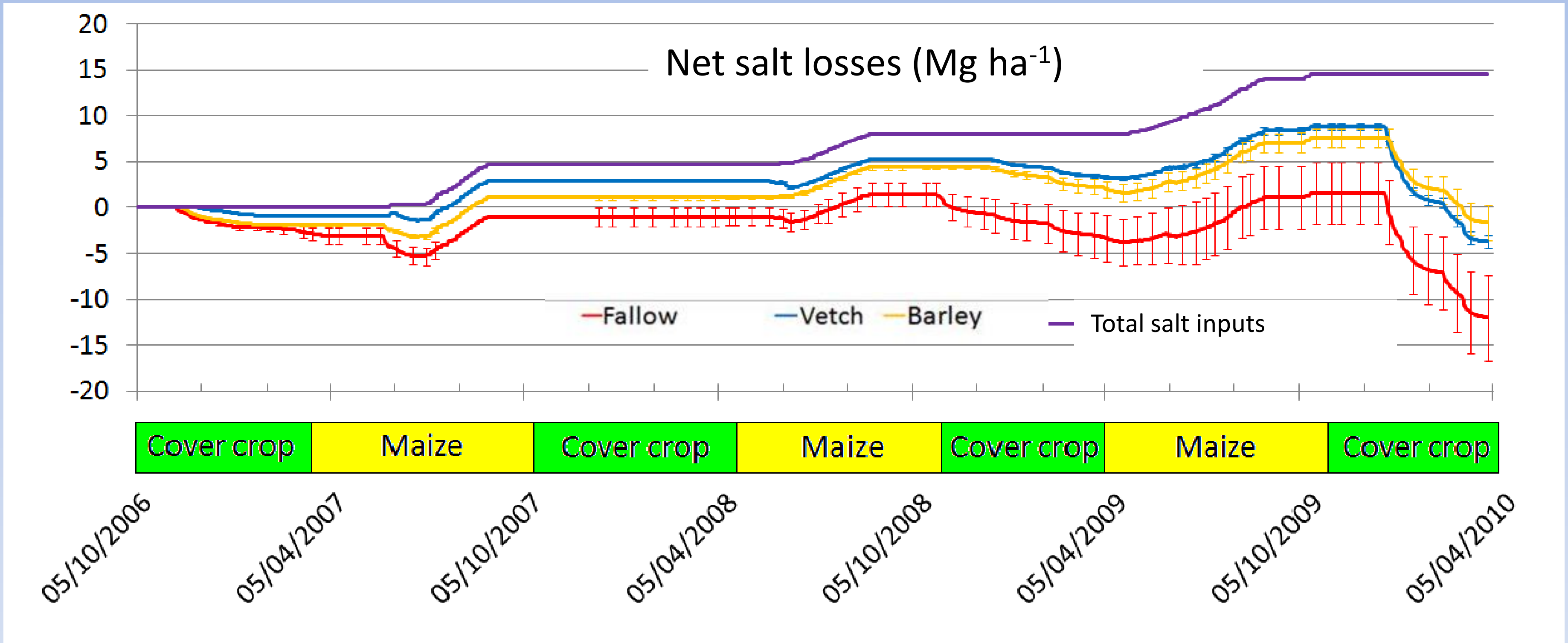


N uptake by maize from other sources than mineral fertilizer



European Journal of Agronomy (2011) 34: 133-143

Results: Salt leaching



Nitrate vulnerable zones

Reasons for nitrate polution?

Nitrate Vulnerable Zones linked to husbandry and surplus manure production

Nitrate Vulnerable Zones linked to irrigated areas, where highly productive crops are often overfertilized