Fate of isoxaflutole and its diketonitrile metabolite under conventional and conservation tillage in an irrigated continuous-maize field

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Context

National context: generalization of water resources pollution by pesticides…

Economic context: Midi-Pyrénées region = 2nd region for maize production in France

Agronomic context: Typical maize production management in the region:

- 80 % of the production is in continuous maize with more than 60 % irrigated.
- Tillage usually included a mouldboard ploughing (30-cm depth) at the end of the winter
- Soils are unprotected during the inter-crop (from November to May)

Environmental context:

⇨ In the region, this system of production has generated several environmental problems (nitrate, atrazine)

⇨ Now atrazine is forbidden: there is a need for development of new strategies to control weeds in continuous maize systems

<u>Scientific</u>

Conventional tillage (CT) / Conservation tillage (MT)

***vs.* Pesticide ?**

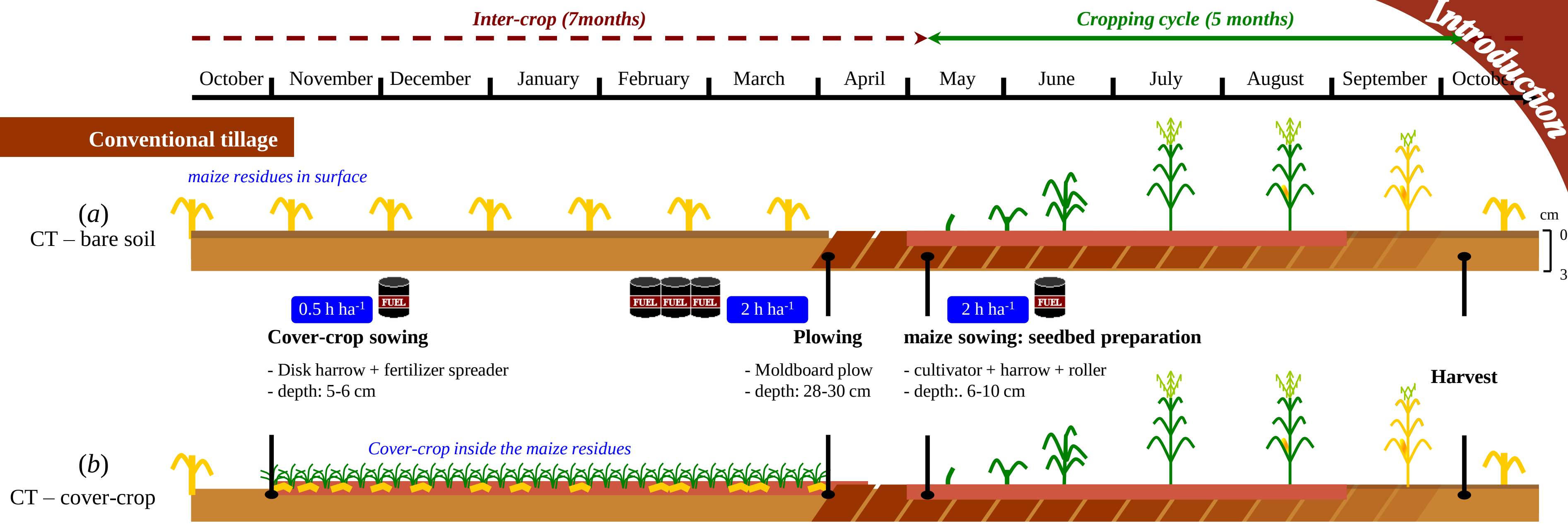
→ Organic carbon content ↗ surface → pesticides sorption ↗ (Locke et al., 1997)
Desorption: very few studies… tend to increase under MT (Ding et al., 2002)

→ Degradation: highly contrasted results !

→ Runoff and erosion: MT are efficient to reduce erosion, but runoff depends on climatic conditions (Fawcett et al. 1994)

→ Leaching: contrasted results but for no-tillage systems leaching of pesticides increases (Watts & Hall, 1996)

There is a need to evaluate and/or design new cropping systems to both maintain weed control efficiency and limit environmental impacts



The cropping systems

The cropping systems: soil surface differences

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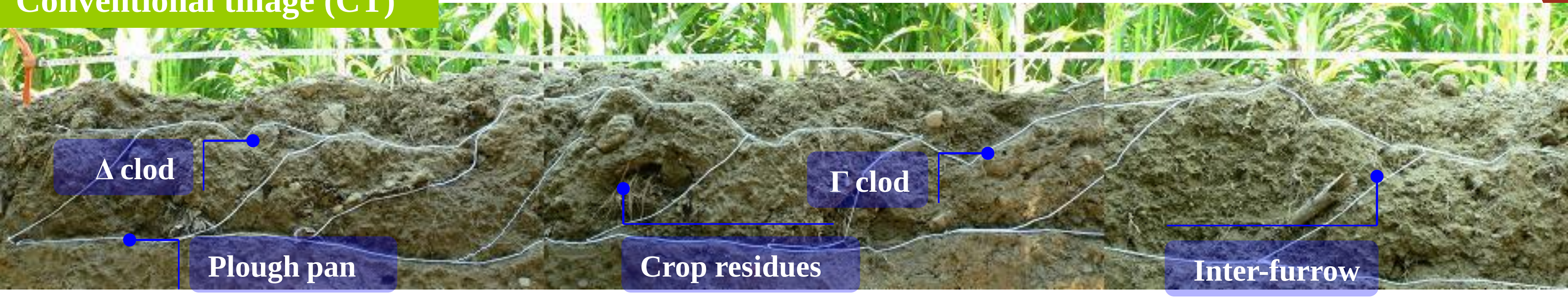
+

Conventional tillage (CT)

Conservation tillage (MT)

The cropping systems: subsurface differences

Conventional tillage (CT)



(Manichon, 1982; Roger-Estrade et al. ,2004)

Conservation tillage (MT)

→ Consequences on water dynamics and solutes transport

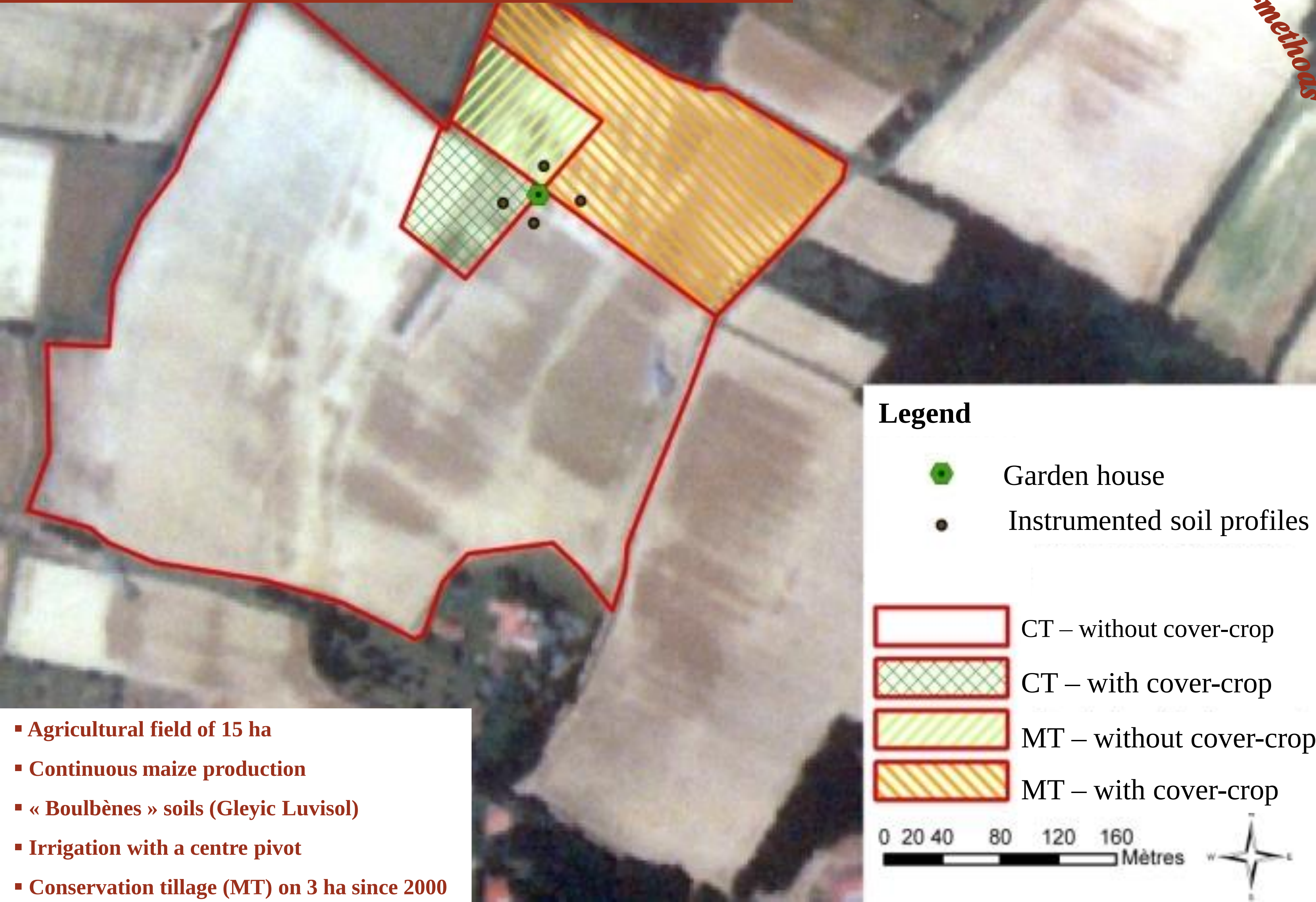
Objectives of the study

Evaluate the effects of tillage practices (conventional vs. conservation tillage ; inter-crop with or without cover-crop) on:

1- Isoxaflutole degradation and formation of diketonitrile

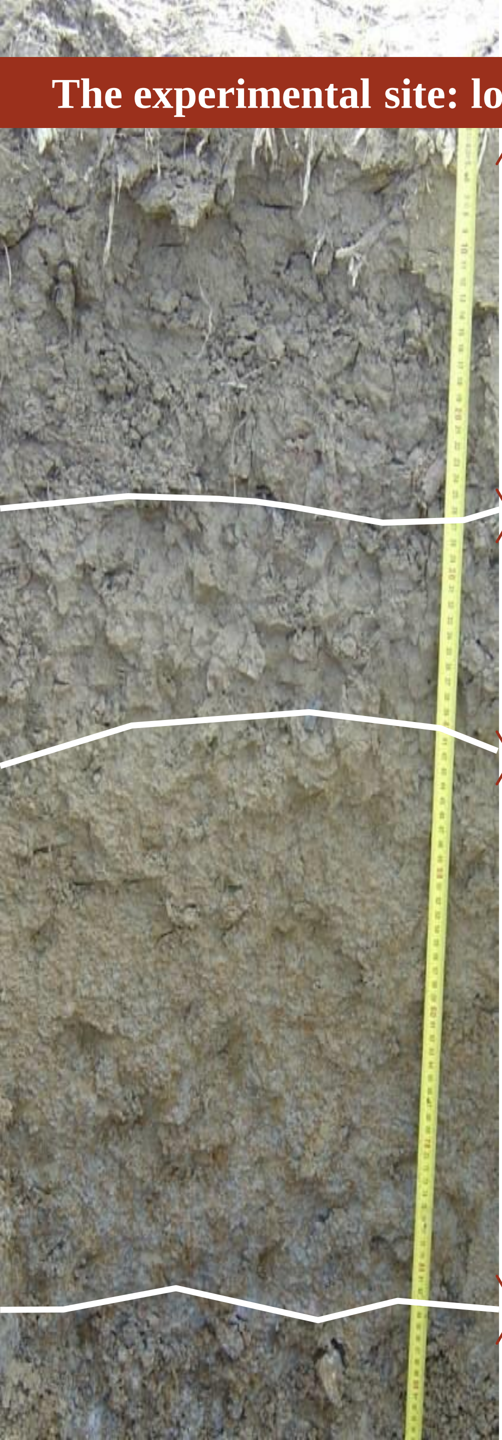
2- Leaching potential of isoxaflutole and its diketonitrile metabolite

The experimental site: localisation and soil characteristics



- Agricultural field of 15 ha
- Continuous maize production
- « Boulbènes » soils (Gleyic Luvisol)
- Irrigation with a centre pivot
- Conservation tillage (MT) on 3 ha since 2000

The experimental site: localisation and soil characteristics



0-28cm

28-55cm

55-80cm

80cm

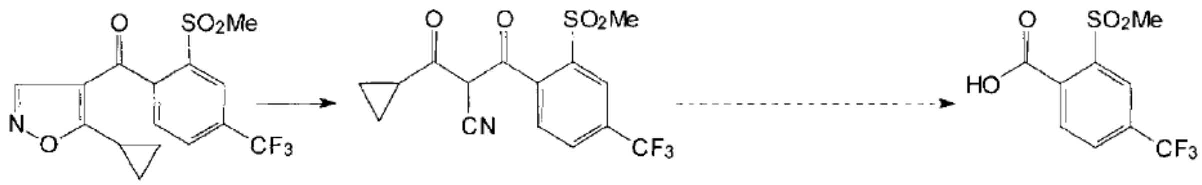
Main features of the Boulbènes soil types:

- Loamy soils with unstable structure
- Low organic matter level
- High sensitivity to crusting
- Hydromorphic profile

	Horizon	Prof.	pH	Clay	Silt	Sand	OC	$CaCO_3$
		(m)		(g kg^{-1})				
CT	LA1	0-0.10	7.2	282	538	166	8.18	9
	LA2	0.10-0.28	7.2	279	560	144	8.91	12
	Btg1	0.28-0.55	7.5	394	489	108	3.64	18
	Btg2	0.55-0.80	6.9	450	439	103	3.11	0
MT	LA1	0-0.10	7.3	265	569	145	8.72	15
	"LA2"	0.10-0.28	7.2	276	559	149	8.35	9
	Btg1	0.28-0.55	7.2	387	476	123	4.72	13
	Btg2	0.55-0.80	6.7	447	402	144	4.39	0

Isoxaflutole (IFT) properties

- Proherbicide, isoxazoles



- Annual grasses and broadleaves weeds, roots uptake
- Pre-emergence of maize (75 g ha^{-1})
- Inhibitor of the biosynthesis of carotenoids

- **IFT**: **low solubility** in water (6.2 mg L^{-1}), **rapidly degraded** (DT_{50} : 1.4-3 j), **good retention** on organic compounds (K_{OC} : 122 L kg^{-1})
- Degradation: formation of the **diketonitrile** (**DKN**) with a **higher solubility** (300 mg L^{-1}), a **lower retention** (K_{OC} : 92 L kg^{-1}) and a **higher persistence** (DT_{50} : 8-16 j)

Sampling procedure: soil

- Before treatment: sampling of soil from surface to 80-cm depth to control initial concentration of IFT and DKN

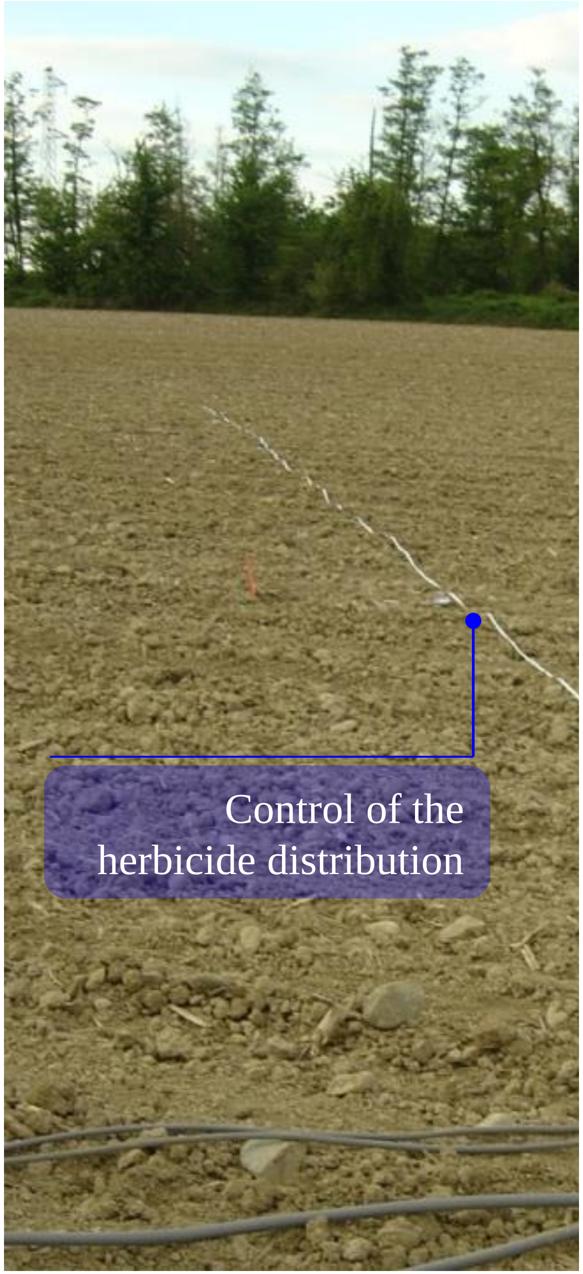
- Treatment day: control of the variability of the treatment with fibreglass paper

- Sampling of soil from surface to a maximum of 30-cm depth

- Sampling time: t_{ini}, t_0, t_2, t_3, t_5, t_7, t_{11}, t_{14}, t_{21}, t_{28}

- Storage of frozen samples (-18°C) until analysis

- Analysis by HPLC-MS/MS



Sampling procedure: water

- Ceramic cups: 4 by soil pit at 20 and 70 cm-depth
- Fibreglass wick lysimeters: 2 by soil pit at 40 cm (25x25 cm). Fibreglass wick length: 70 cm
- Sampling of soil water with ceramic cups and fibreglass wick lysimeters
- Storage of frozen samples (-18°C) until analysis
- Analysis by HPLC-MS/MS

General data

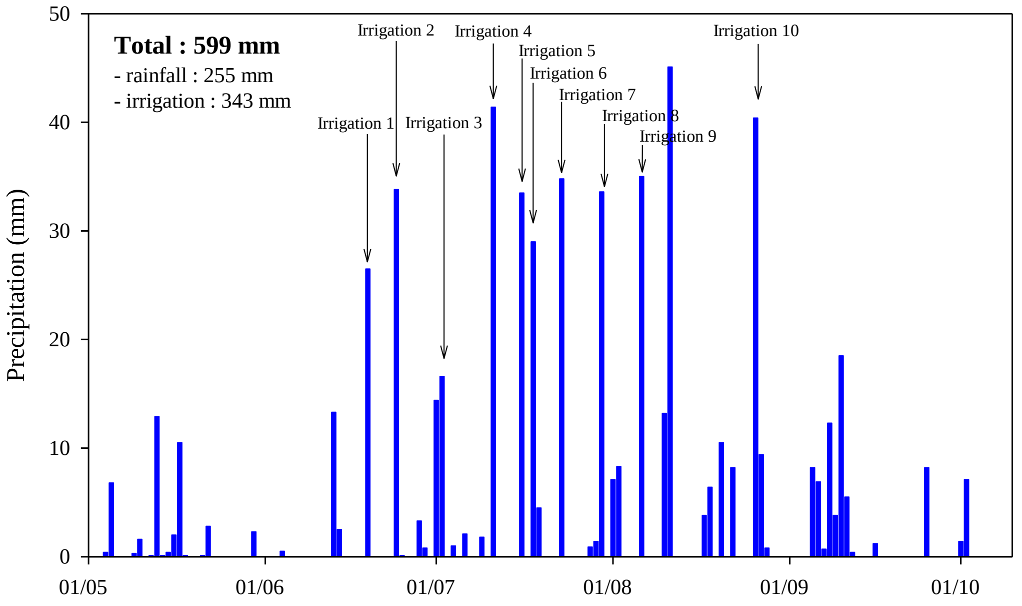
- In soil samples: Limit of quantification (LOQ) ≈ **0.01 mg a.i. kg^{-1} soil**
- In water samples: LOQ depends on collected volumes (V)
  - If V < 50 ml → LOQ = **0.2 µg L^{-1}**
  - If V > 1000 ml → LOQ = **0.02 µg L^{-1}**

In 2005:

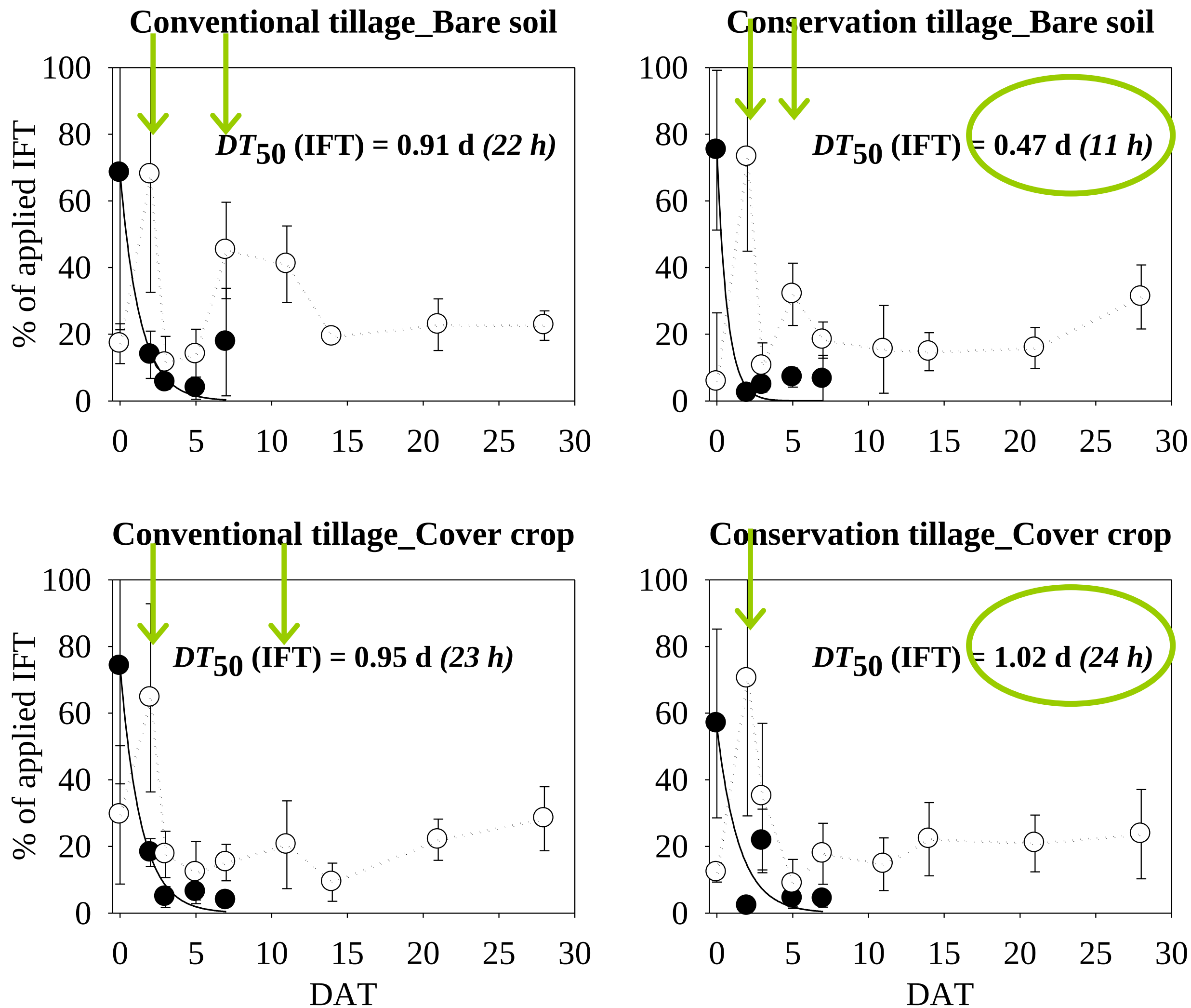
- **400 soil samples** were analysed from treatment day to 28 DAT
- **73 water samples**: **(**14 from the ceramic cups and 59 from the fibreglass wick lysimeters

<u>Rainfall data during the cropping season</u>

- Total precipitation: **599 mm**
- First rainfall: **1 DAT – 7.6 mm in 6 h**



Persistence of isoxaflutole



●: IFT
○: DKN
} in soil samples (in % of applied IFT)

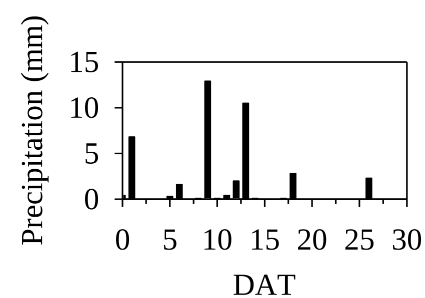
1 IFT DT_{50} was short (<1 d)
No detection of IFT 7 DAT

2 No effect of tillage on IFT DT_{50}
But… a longer persistence under MT with cover crop: ***Sorption*** ?

→IFT hydrolysis was catalysed by retention on solid phase (Rice et al., 2004)

But…

→ Sorption of IFT on organic matter was found to increase DT_{50} (Rouchaud et al,, 2002)



3 Increase of DKN with rainfall events

PURPAN

Water and herbicide leaching

1 Cumulative water drainage ≈ 7 L under MT_Bare soil and < 7 L under MT_Cover-crop

2 Cumulative leaching of DKN reached about 8 % of applied dose under MT_Bare soil and < 2 % under MT_Cover-crop

→ Lower initial water content in the soil profile under cover-crop → increase sorption

→ Quantity and/or nature of the residues *vs.* sorption and degradation of DKN…

Water drainage (mL)

● : DKN concentration in water (in % of applied IFT)

○ : Cumulative loss of herbicide

1 Cumulative water drainage ≈ 14 L under CT_Bare soil & CT_Cover-crop

2 Cumulative leaching of DKN reached about 15 % of applied dose at the end of the growing season

3 Maximum DKN concentration was 32 µg L^{-1} 64 DAT (but in a low volume)

- Tillage practices had no effect on the in-field degradation of isoxaflutole
- Residues on soil surface seemed to slow down degradation rate of IFT

Effect of interception and retention ?

- Migration in soil was faster and more important under conventional technique (data not shown)

- Water drainage was two times higher under conventional technique

- Herbicide leaching was between 2 and 7 times lower under conservation technique, with the lowest leaching under the cover-crop plot

Retention processes and/or degradation were modified by tillage and residues management ?

Thank you.