Nitrogen leaching from organic and conventional arable crop rotations

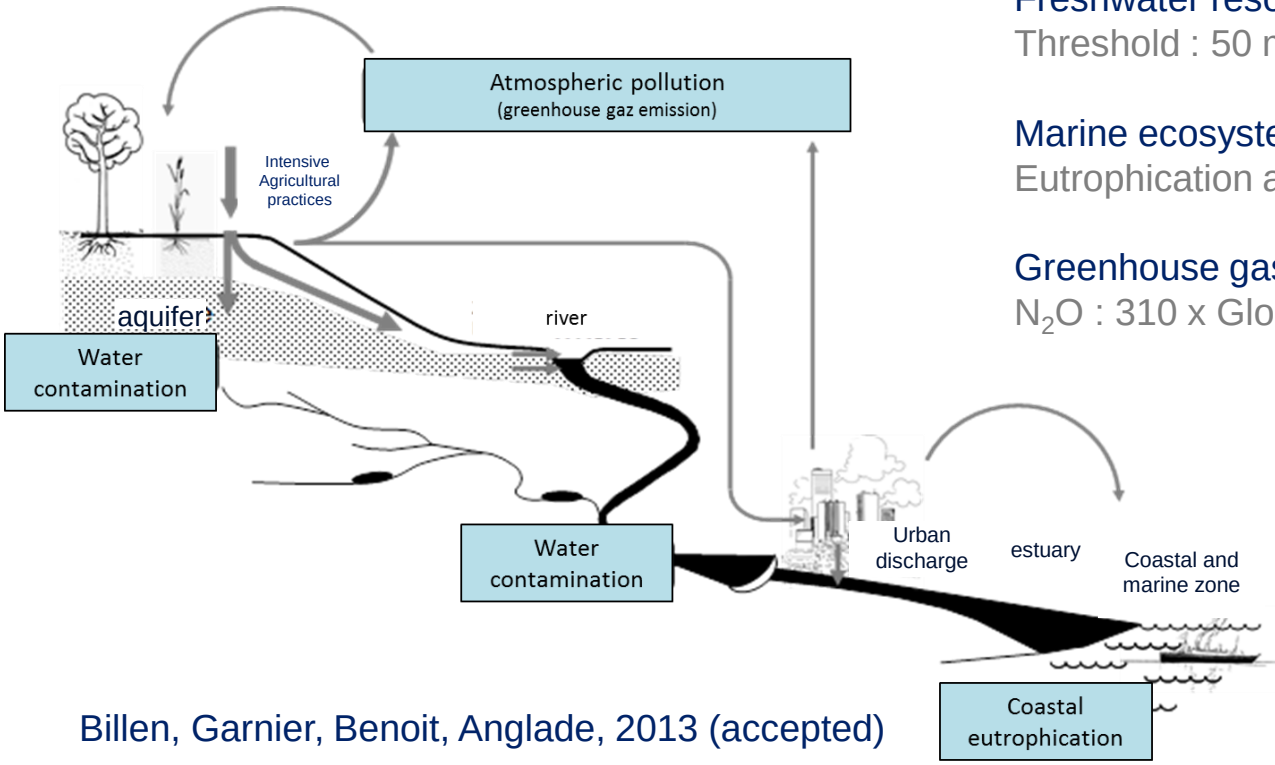
Case study : Seine watershed, France

M. Benoit, J. Garnier, G. Billen, J. Anglade, B. Mercier & A. Azougui

Nitrogen cascade in arable crop areas

Intensive agricultural practices impacts on environment

The Nitrogen Cascade in arable crop areas of the North of France



Billen, Garnier, Benoit, Anglade, 2013 (accepted)

Diffuse pollution impacts from agriculture

Freshwater resource, above water drinking standard
Threshold : 50 mgNO_3.l^{-1} or 11mgN.l^{-1}

Marine ecosystem
Eutrophication and algal bloom on coastal area

Greenhouse gas emission
N_2O : 310 x Global warming potential CO_2

Nitrogen diffuse pollution from agriculture has today a major impact on water quality

References on conventional leaching in France

Nitrogen sub-root concentrations based on 7 publications

Location	10 sites in the North of France in arable crops
Measurement tools	Water : drained water, lysimeter, ceramic porous cups Soil : Nitrogen balance
Period of study	Long period survey (from 3 to 13 years) 34 years (1976-2010)
Rotation type	Intensive cereal crop, as wheat, oat, maize Mostly silt loam
Sub-root concentration	**Average for cereal crops: 27 ± 4 mgN.l^{-1}**
References	*Arlot et Zimmer, 1990; Machet et Mary, 1990; Chapot, 1990; Gaury, 1992; Denys, 1990; Constantin et al., 2010*

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No peer-review paper on organic leaching in France

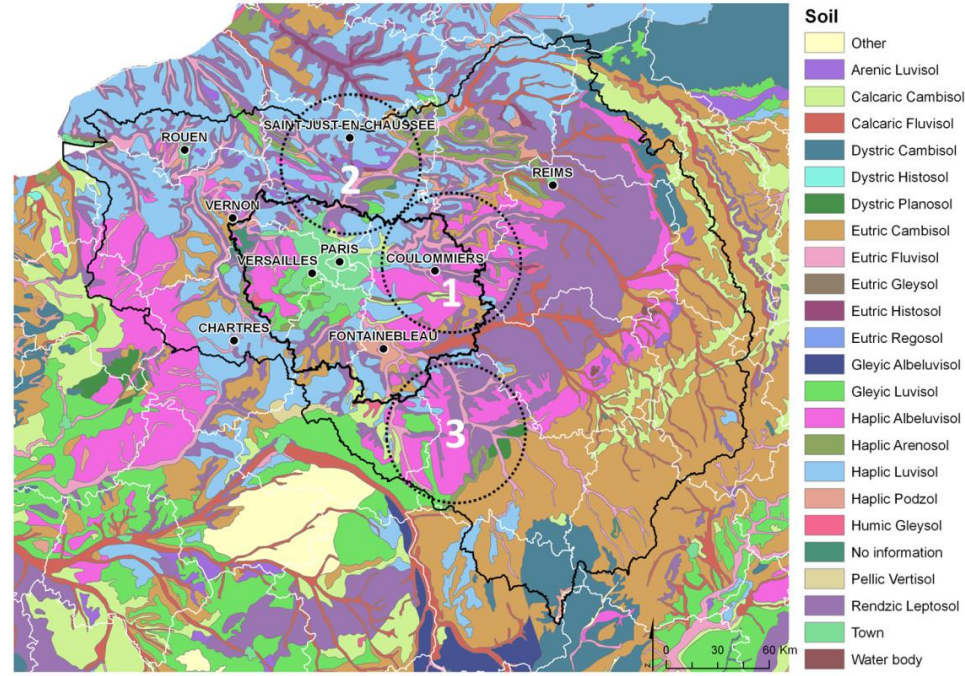
Measurements network in the Seine watershed

Organic, mixed and conventional systems in arable crops farms

Farms localization in 2012-2013

East	Mixed (organic and conventional) (OF1, OC1)
	Organic farm (OF2)
	Conventional farm (OC2)
North	Mixed (organic and conventional) (OF3, OC3)
	Organic farm (OF4)
South	Organic farm (OF5)

Seine watershed of soil map with farms localization



Organic farming : 0.9% utilised agricultural land

8 practices on complete arable crop rotations i.e. 39 organic and 8 conventional parcels

Organic and conventional farms characteristics

Differences in organic and conventional rotations

Farming	Organic	Conventional
Localization	North, East and South	North and East
Numbers of practices	5	3
Conversion time	3 to 10 years	
Crops rotation lenghts	8	3

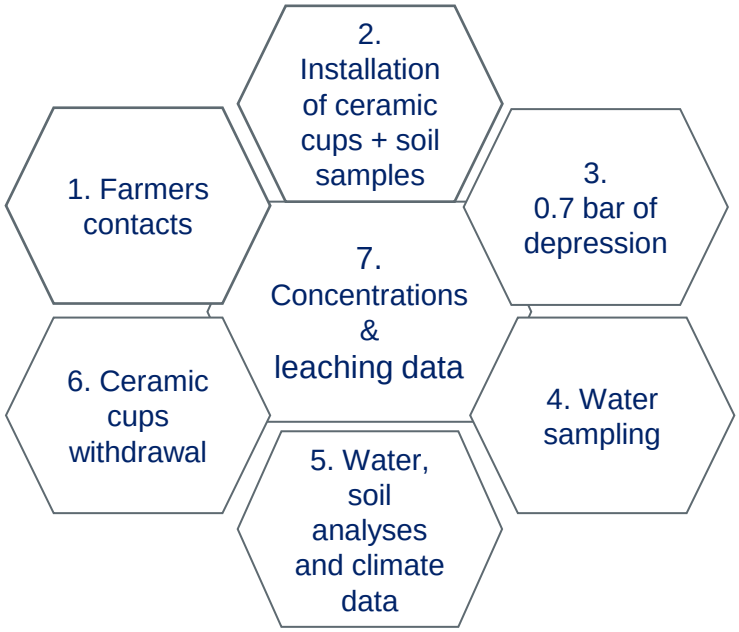
Organic and conventional farms characteristics

Differences in total nitrogen inputs

Farming	Organic	Conventional
Localization	North, East and South	North and East
Numbers of practices	5	3
Conversion time	3 to 10 years	
Crops rotation lenghts	8	3
Exogenous Fertilization (kgN/ha/yr)	33	154
Biological nitrogen fixation (khN/ha/yr)	109	105
Total Nitrogen inputs (kgN/ha/yr)	**136**	**259**

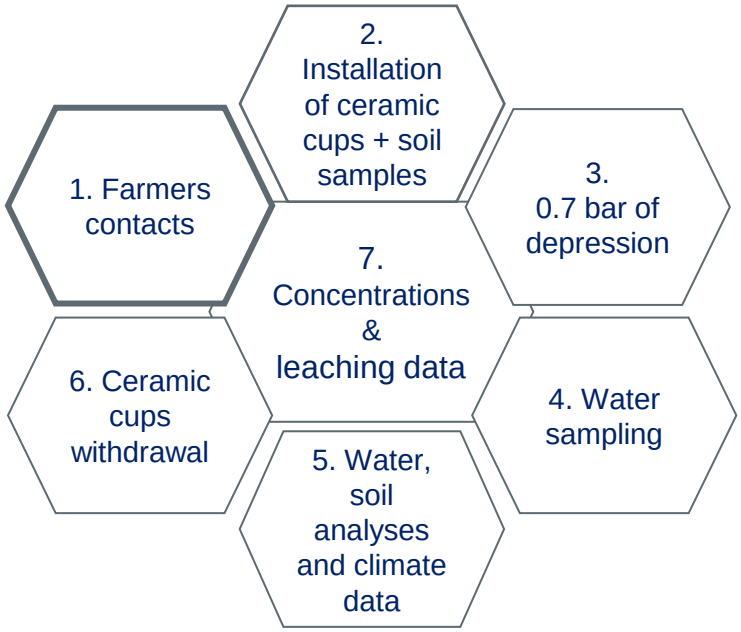
Measurements network based on vertical ceramic cups

Process to get leaching data in commercial farms



Measurements network based on vertical ceramic cups

Network set up with farmers



G. Billen with territorial agents

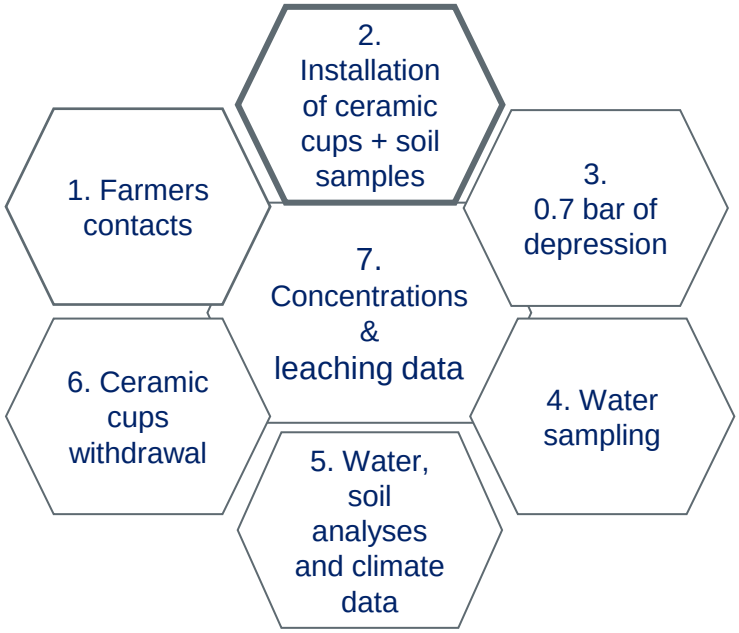
Farmer interview in the field

Farmers are linked to

1. Conventional and organic agricultural groups
2. Water agencies
3. Territorial agents

Measurements network based on vertical ceramic cups

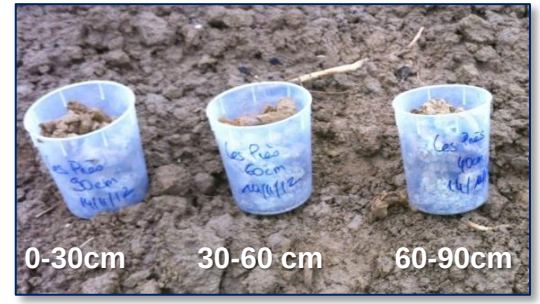
Ceramic cups installation and soil samples



230 ceramic cups implemented

Soil analysis

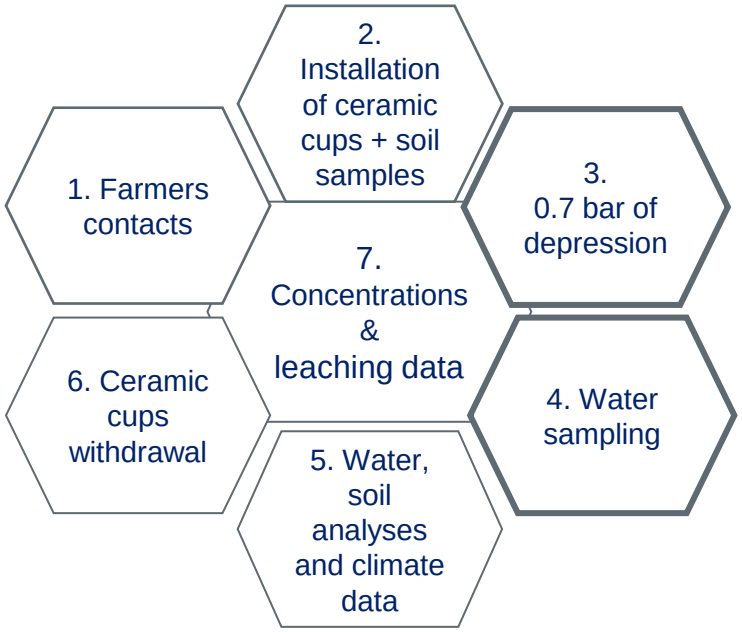
1. Texture : % Silt, clay, sand
2. Physicochemical properties : organic carbon, total nitrogen, C/N, soil organic matter, pH and water-filled pore space.



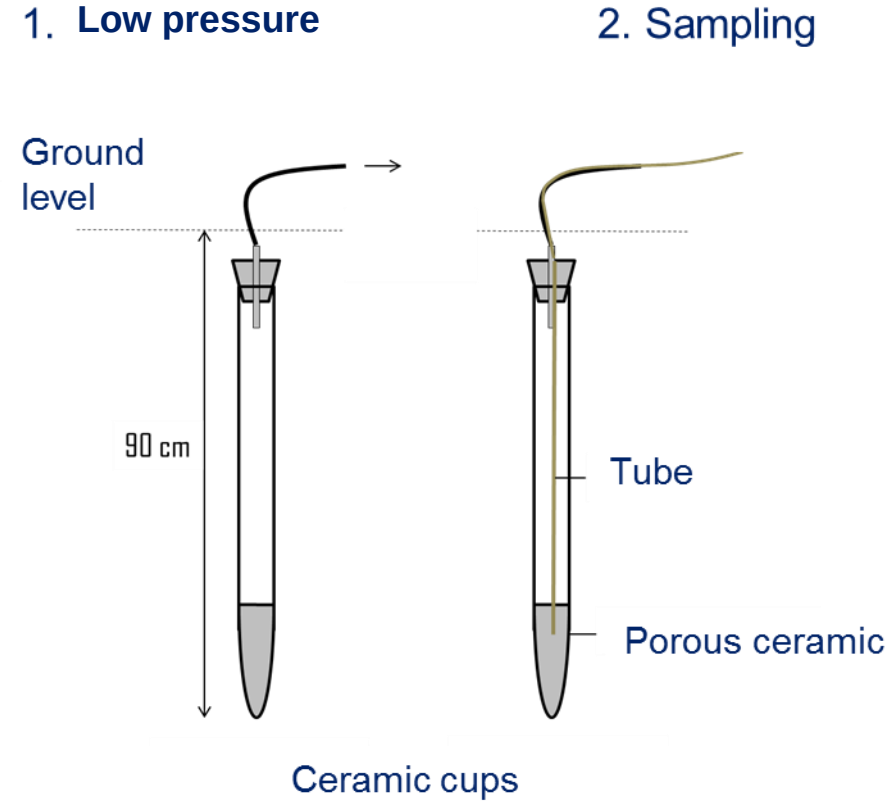
234 soils samples collected

Measurements network based on vertical ceramic cups

Ceramic cups operations



Handling in two steps for ceramic cups operation

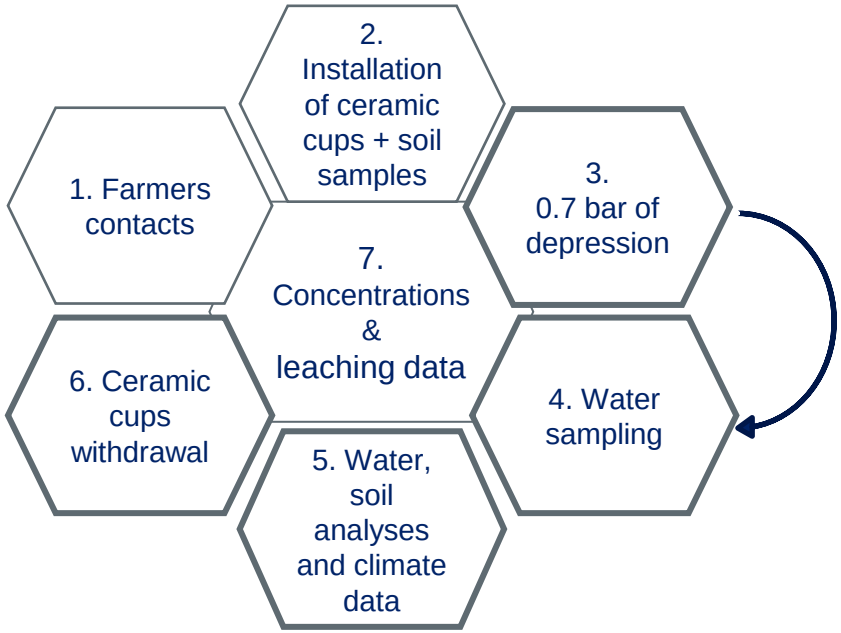


Ceramic cups operations

1. Low pressure with a vacuum pump (0.7 bar)
2. Water suction through porous ceramic
3. After 48 hours, samples collect to a flask until nitrogen analysis

Measurements network based on vertical ceramic cups

Collecting periods in 2011-2012 and 2012-2013



Total water handlings & analysis in 2012-2013

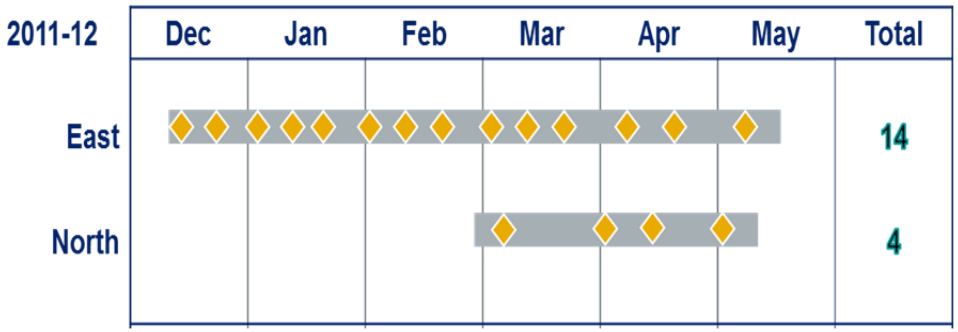
6 months drainage period

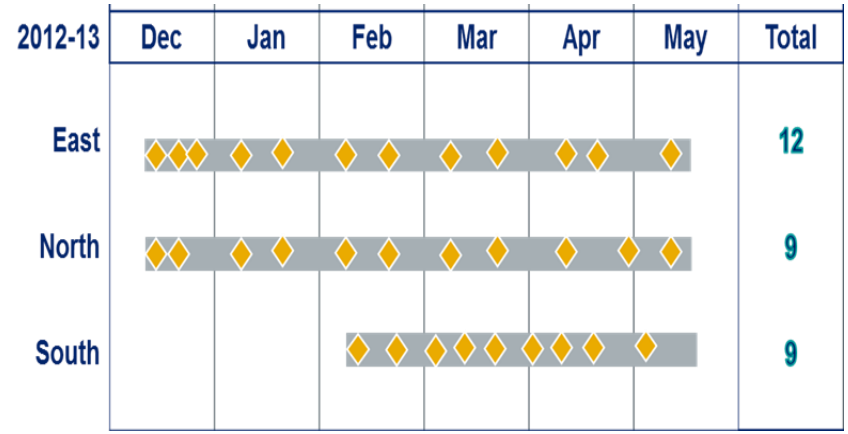
10 dates of samples collectings

230 ceramic cups

= 2500 sub-root water analysis

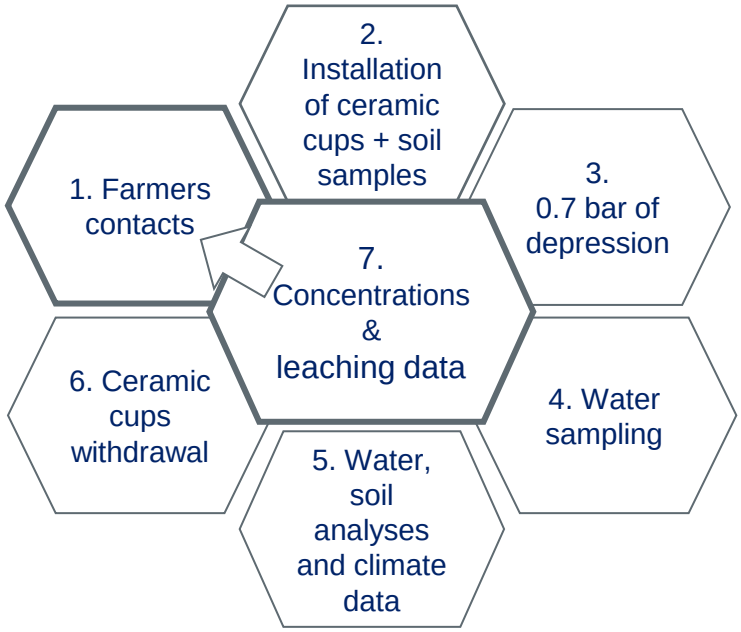
Collecting timetables in 2011-2012 & 2012-2013





Measurements network based on vertical ceramic cups

Results and communications



Participation in regional organic farming seminar in 2012

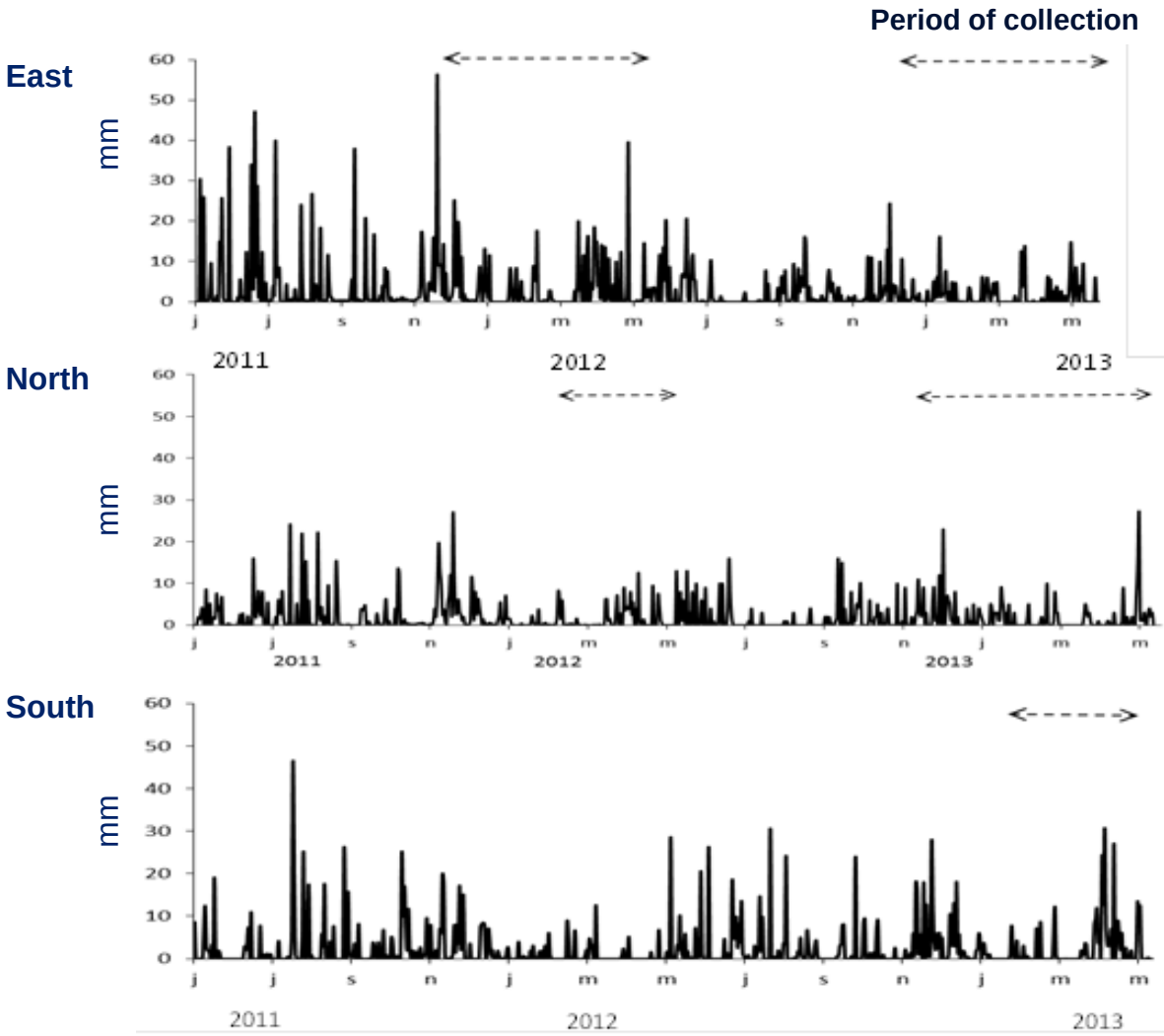
Communications to farmers

1. Regional farming events
2. Individual results reports
3. Web site : http://www.fire.upmc.fr/abac/
4. Invitations to annual steering commitees with researchers from different Institutes

Participative network with farmers involvement

Climate data in sites studied

Rainfall variations from 2011 to 2013



East

2012-2013 : small rainfall variations

Total annual rainfall : 700mm

Period of collection : 300mm

North

Smaller downpours than East

Total annual rainfall : 700mm

Period of collection : 300mm

South

Higher and more downpours

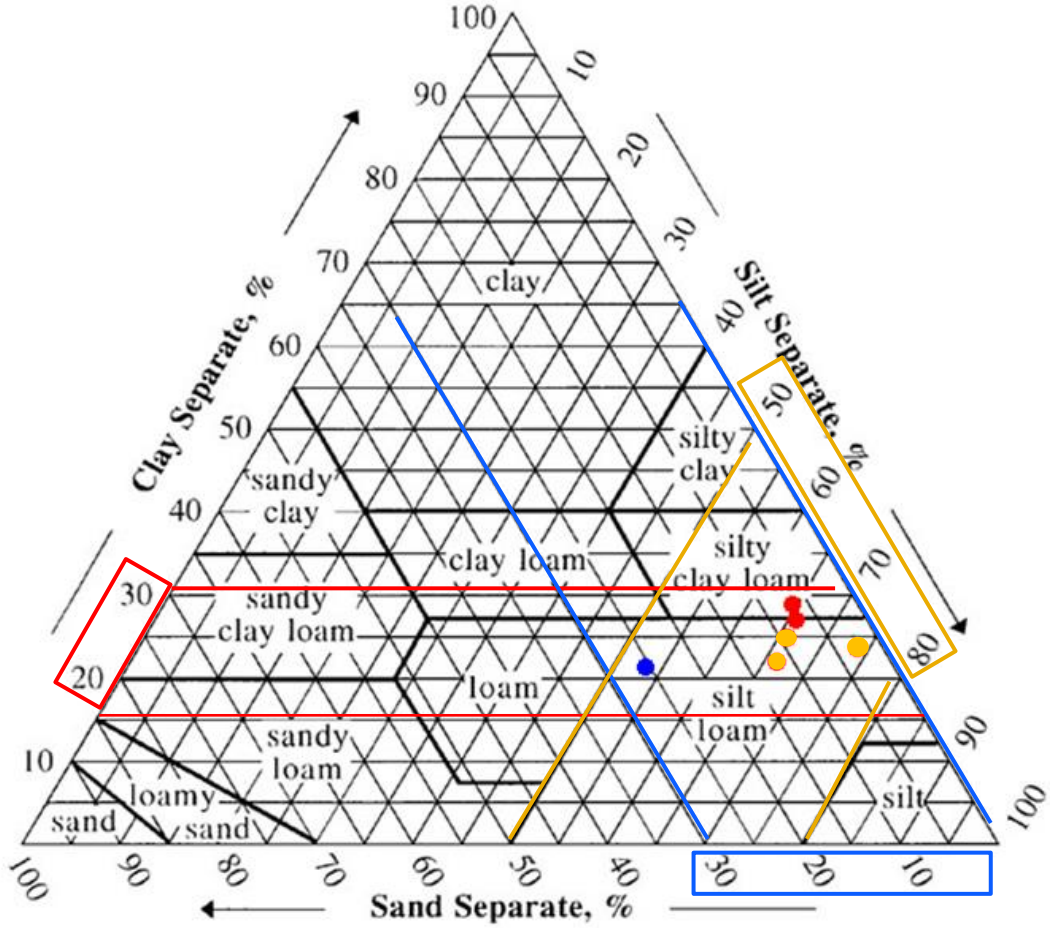
Total annual rainfall : 1000mm

Period of collection : 300mm

Inter annual rainfall variations between years and regions

Soil characteristics in farms studied

Soil texture triangle with averages per farm



No significant texture differences

between parcels from each farm

(standards deviation < 6%)

Texture averages of farms : silt loam

Silt between 50-80%, maximum in East

Clay between 20-30%, maximum in North

Sand between 0-30%, maximum in South

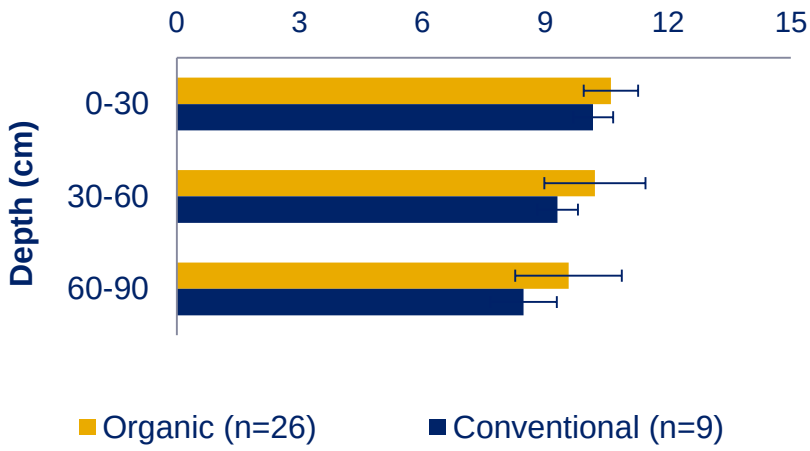
A majority of silt loam soils with regional tendencies

Soil characteristics

Nutrients averages between conventional and organic farms

Soil Organic Matter (g/kg)

in organic and conventional systems



Soil organic matter with no significant differences

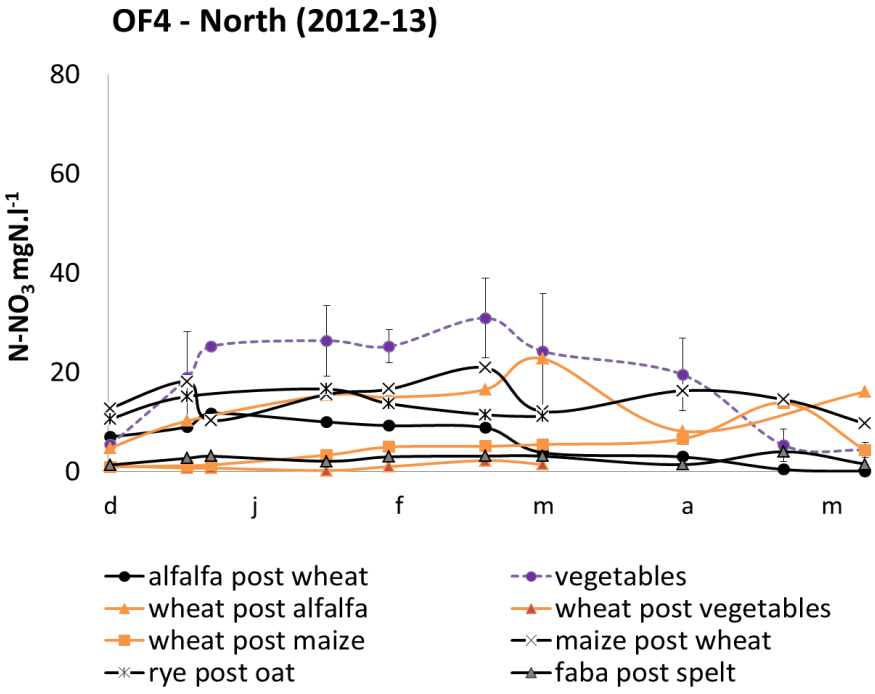
1. in organic vs conventional
2. between regions
3. in long vs short terms organic conversions

Organic and conventional soils do not show significant differences in SOM contents

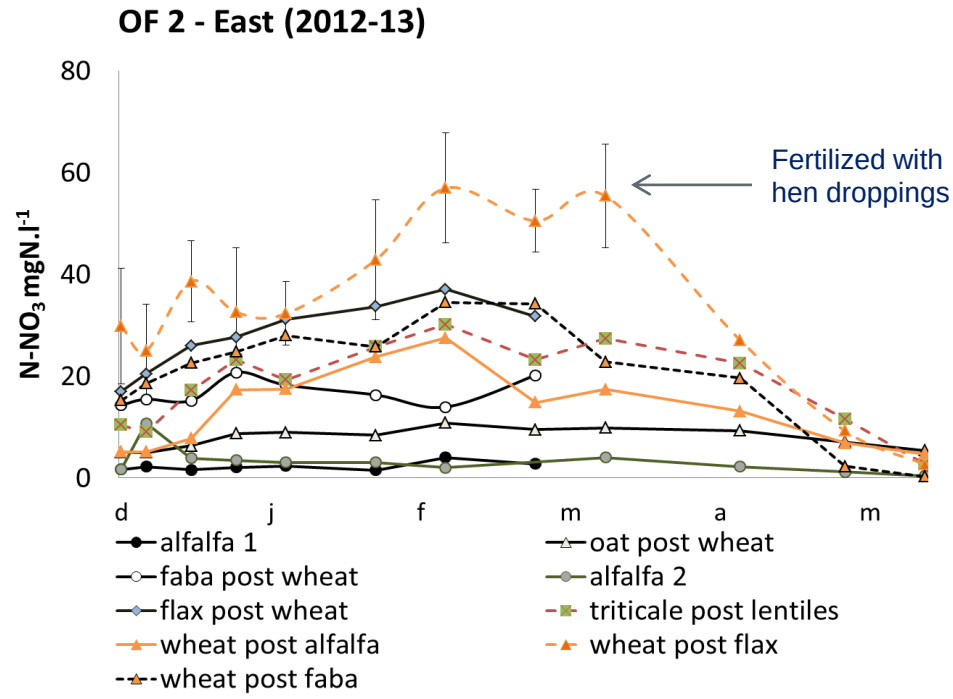
Nitrate concentrations variations in organic farms

Long term organic conversion (10 years)

1.Context
2. Method
3. Results
4. Perspectives



Average on complete rotation OF4 : 8.4 mgN.l^{-1}

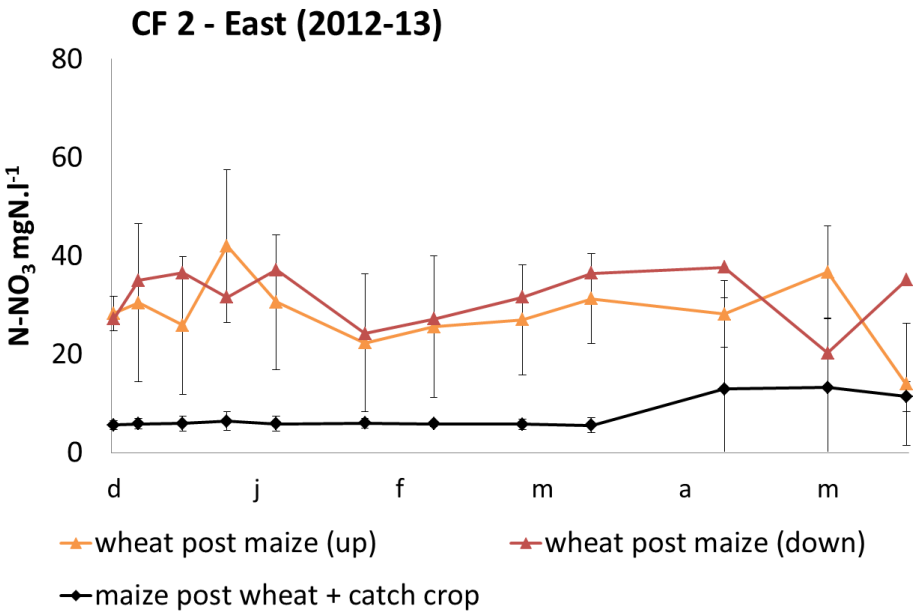


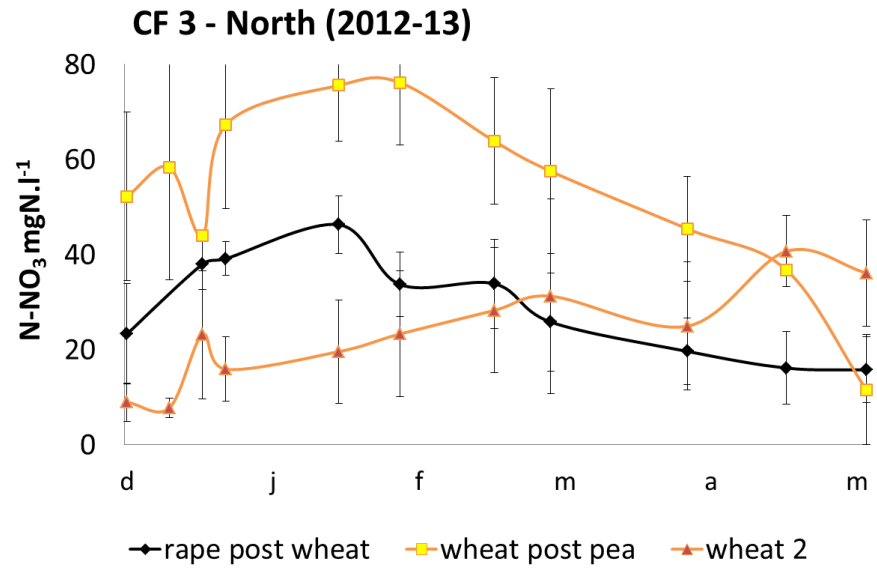
Average on complete rotation OF2 : 16.2 mgN.l^{-1}

Intra & Inter-variations among organic farms

Nitrate concentrations variations in conventional farms

Long term conventional practices





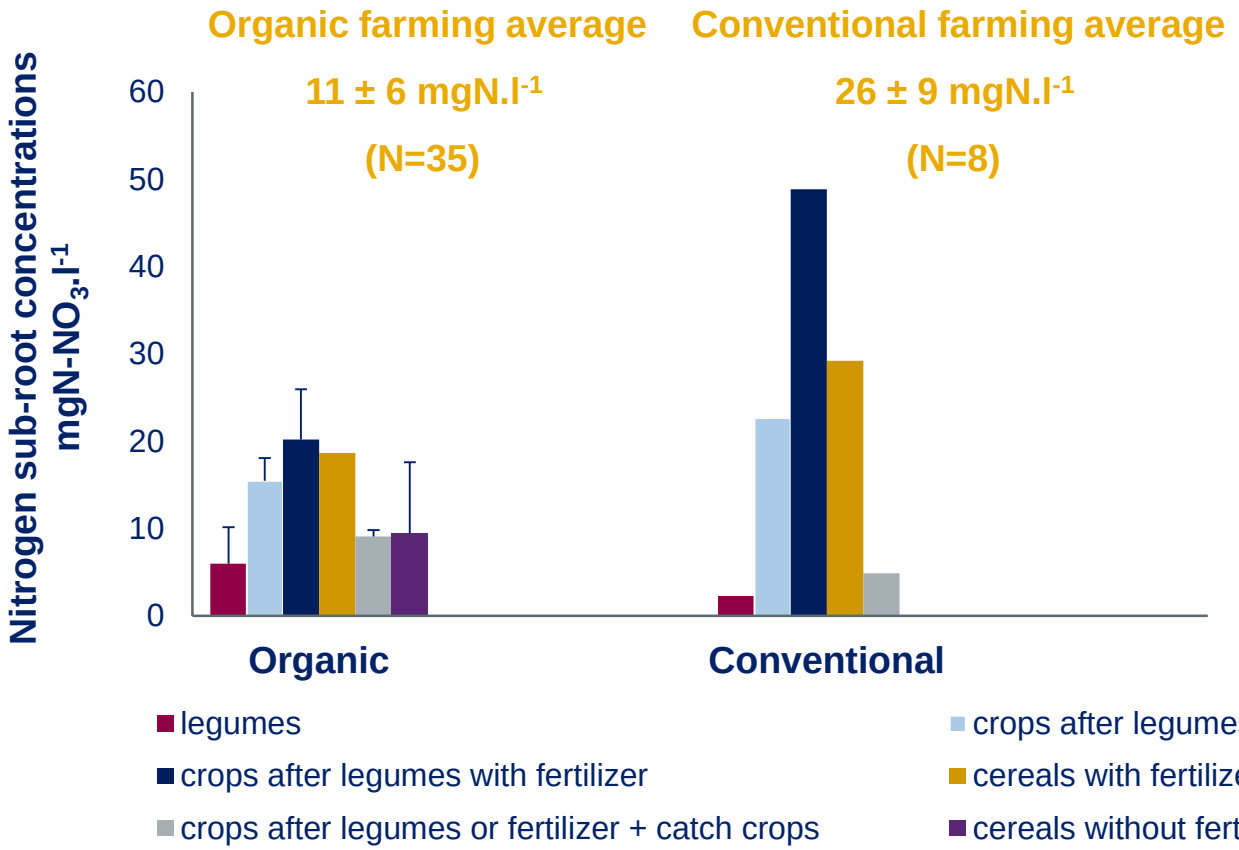
Average on complete rotation CF2 : 18.8 mgN.l^{-1}

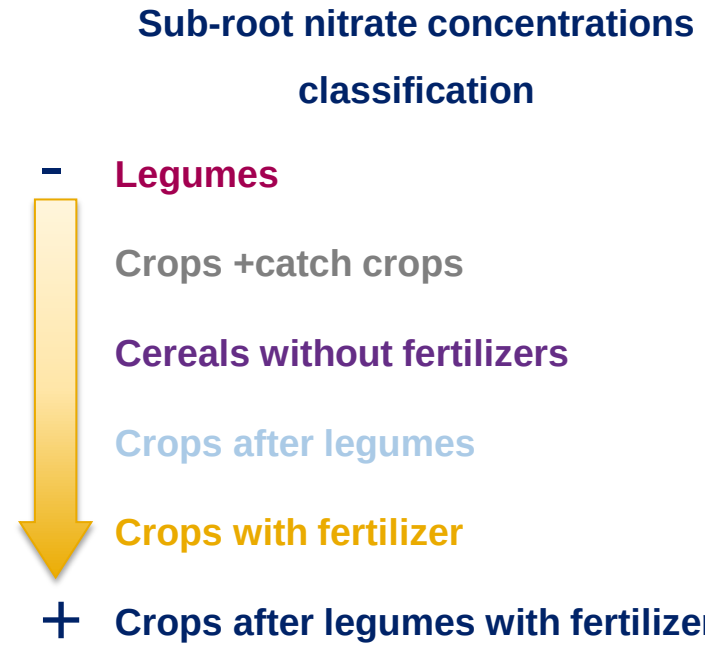
Average on complete rotation CF3 :35.4 mgN.l^{-1}

Intra & Inter-variations among conventional farms

Nitrogen concentrations in function of crops

Sub-root concentrations averages in organic and conventional systems

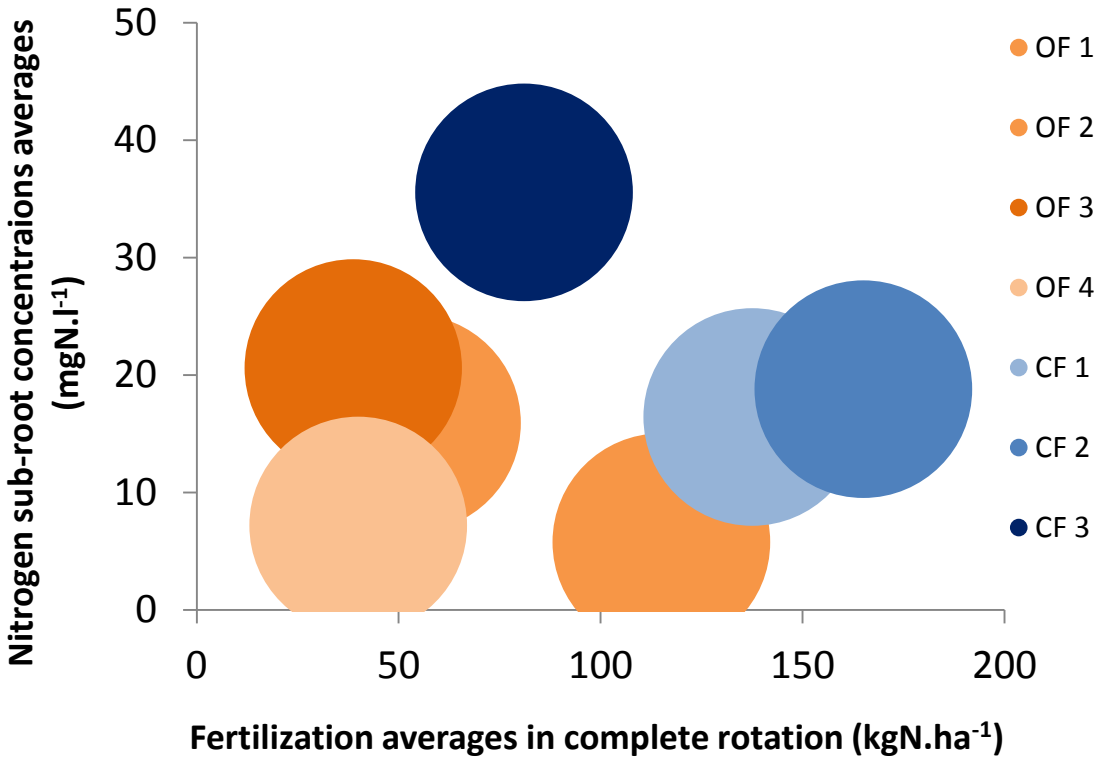




Organic farming nitrate is, in average, below the drinking water standard

Inter-variation nitrate concentrations in the network

Sub-root concentrations averages in function of fertilization averages



Farms sub-root concentration averages

Organic farming 5 to 20 mg.l^{-1}

Conventional farming 15 to 35 mg.l^{-1}

Factors variations on complete rotation

Total fertilization

exogenous + biological nitrogen fixation

Total nitrogen export (yields)

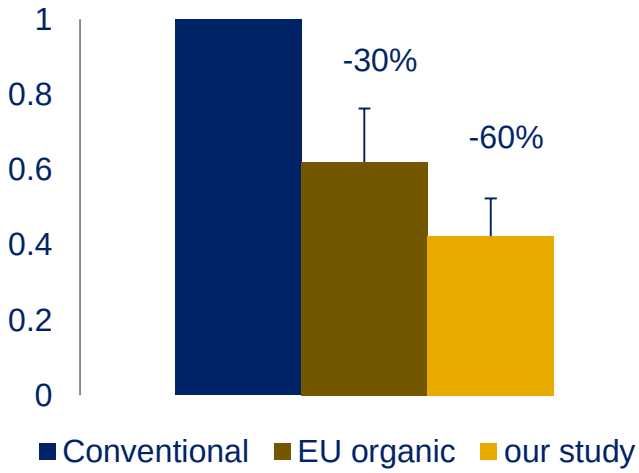
Soils and climatic data (runoff water)

Farmer practices impact nitrogen sub-roots concentrations

Nitrogen leaching comparison between systems

Does organic farming systems diminish the risk of nitrogen leaching ?

Nitrate concentration ratio between organic and conventional farming



EU references on ogranic vs conventional leaching in cereal crop fields

Methods

Long term studies (3 to 7 years) on different soil types

Lysimeter, ceramic cups, N content, model

Results

Ratio Organic / Conventional : - 30%

Our study : - 60%

Berg et al., 1998; Haas et al., 2002; Hansen et al., 2000; Korsaeth et al., 2000; Kristensen et al., 1994; Stopes et al., 2002.

Sub-root nitrate concentrations are -30 to -60% lower in organic vs. conventional systems

Nitrogen leaching reduction practices

How can organic farming systems decrease the risk of nitrogen leaching ?

1. **Use of catch crops for after legumes or spring crops**

   catch crop ≠ cover crop (green manure)

   increase mineralization potential in long term (Beaudoin et al, 2002)

2. **Fertilization use on and after legumes maximum reduction**

3. **Alfalfa management (last harvest period, annual exportation…)**

   N soil balance after winter (Justes et al., 2001)

Organic alfalfa and wheat in june 2012

Perspectives

How can organic farming systems decrease the risk of nitrogen leaching ?

To be continued

1. A sampling network maintained and enlarged in 2013-2014 (+ 4 farms)
2. Leaching calculation with drainage model to determine water runoff
3. Data analysis according to systems, practices, soil nutriments, climate, annual variaion etc.

More results to come…

1. Vertical vs horizontal ceramic cups installations comparison
2. Nitrogen leaching calculations with soils nitrogen balance vs ceramic cups
3. Surplus vs observed nitrogen leaching comparison
4. Global nitrogen balance in organic farm system

   with fertilization practices, yields, greenhouse gaz emission and leaching data

Questions & Answers

Thanks for your attention !

References

Askegaard, Olesen, Rasmussen, Kristensen, 2011.Nitrate leaching from organic arable crop rotations is mostly determined by autumn field management. Agriculture, ecosystem and environment.

Arlot et Zimmer, 1990, Drainage agricole et lessivage des nitrates. Nitrate Agriculture Eau INRA 1990 - Réunion Internationale

Billen, Garnier, Benoit, Anglade, 2013.The Nitrogen Cascade in arable crop areas of the North of France.

Machet et Mary, 1990, Effet de différentes successions culturales sur les risques des pertes de nitrate en région de grande culture. Nitrate Agriculture Eau INRA 1990 - Réunion Internationale

Chapot, 1990, Estimation sur lysimètres de l'incidence de l'introduction d'un engrais vert (moutarde blanche) dans une rotation blé-maïs sur la lixiviation des nitrates. Nitrate Agriculture Eau INRA 1990 - Réunion Internationale

Denys, 1990. Conséquences de l'organisation de l'azote minéral d'un engrais sur la disponibilité pour la plante et sur la lixiviation. Nitrate Agriculture Eau INRA 1990 - Réunion Internationale

Constantin, Beaudoin, Laurent, Cohan, Duyme, Mary, , 2010, Cumulative effects of catch crops on nitrogen uptake, leaching and net mineralization, Plant Soil.

Justes, Thiébeau, Cattin, Larbre, Nicolardot, 2001. Libération d'azote après retournement de luzerne. Perspectives Agricoles - n°264.

Haas, Berg, Köpke, 2002. Nitrate leaching: comparing conventional, integrated and organic in agricultural production systems. Intern Association of Hydrogical Sciences.

Hansen, Kristensen, Grant, Høgh-Jensen, Simmelsgaard, Olesen, 2000.Nitrogen leaching from conventional versus organic farming systems — a systems modelling approach. European Journal of Agronomy.

Beaudoin, Tournebize, Ruiz, Constantin, Justes, 2002. Chap 4. Nitrate et eau en période d'interculture. Conséquences sur les bilans d'eau et d'azote, autres services écosystémiques. Réduire les fuites de nitrate au moyen de cultures intermédiaires.

Korsaeth, Eltun, 1999. Nitrogen mass balances in conventional, integrated and ecological cropping systems and the relationship between balance calculations and nitrogen runoff in an 8-year field experiment in Norway. Agriculture, ecosystem and environment.

Kristensen, Mathiasen, Lassen, hladsen and Reenberg, 1994. A comparison of the leachable inorganic nitrogen content in organic and conventional farming systems. Acta Agric. Scand., Sect. B, Soil and Plant Sci.

Stopes, Lord, Philipps, Woodward, 2002.Nitrate leaching from organic farms and conventional farms following best practice. Soil used management.