



Capacities and limits of two French grassland systems (intensive and extensive) to comply with WFD

Developing tools between science and policy to improve grassland management

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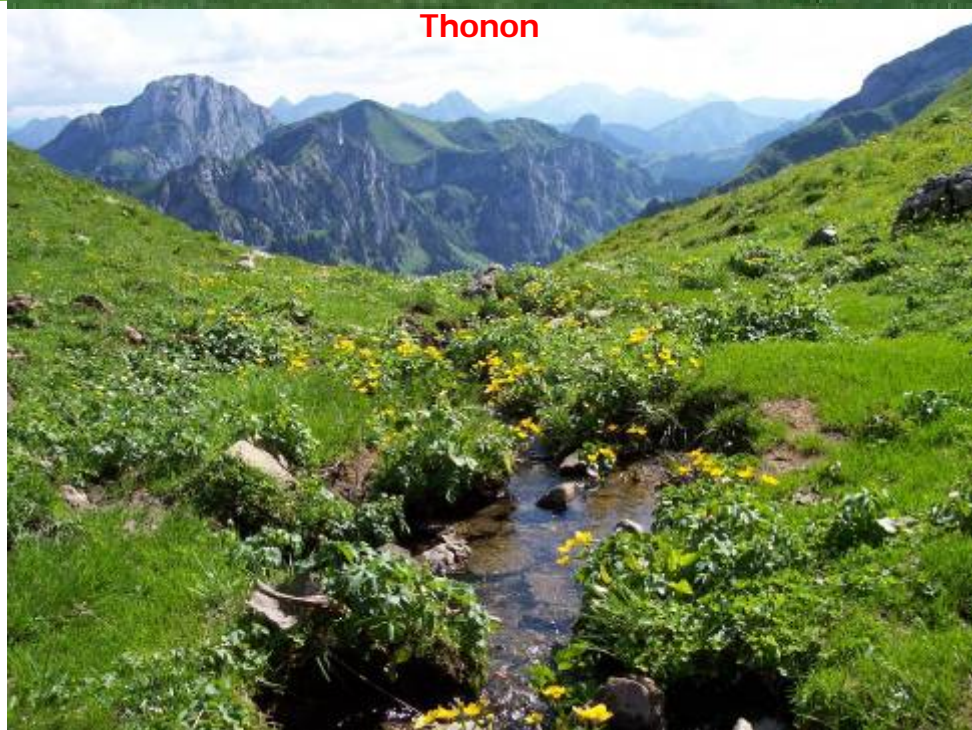
INRA, Agrocampus-Ouest, UMR1069, Sol Agro et hydroSystème, F-35000 Rennes
INRA, UMR CARRETEL, Hydrobiologie lacustre, F-74200 Thonon les Bains

Place and role of grasslands

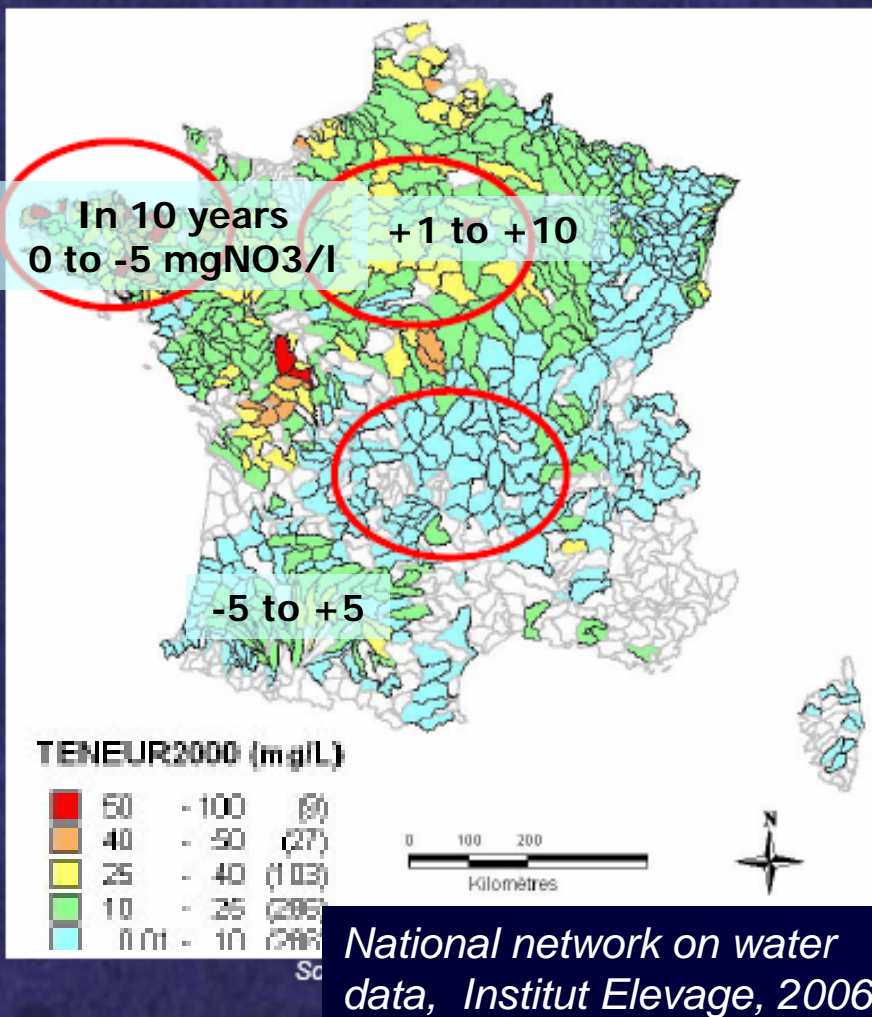
- 43% AA (-30% in 20 years)
- Animal and crop productions are complemented to ensure soil fertility in arable breeding areas (+/- intensive production in lowlands).
but water, air pollutions /nutrient excess..
- Only herbivores grazing permanent pastures can use unploughable soils (+/- extensive use of wetlands, steepy slopes, climatic constraints).
but P, CH₄, bacterial contaminations...
- Grasslands ensure a lot of functions
 - direct effects on : water regime and erosion, C sequestration, N cycling regulation and water quality (*inc. pesticides*), greenhouse gases regulation, biodiversity, landscape diversity, fodder system resilience
 - indirect effects on : SOM and soil quality, including biological activity, control of parasites and weeds..., soil and fauna biodiversity, etc....

Plan

- Backgrounds
 - Cattle systems in France
 - Main water pollutions from diffuse or local sources
 - Challenges of the WFD and french legislation
- Processes
 - Focus on N, P at field, farm or watershed scales
- Tools for diagnosis, mitigation and evaluation
 - Models
 - Decision support tools
 - Multicriteria analysis
- Conclusion - Perspectives

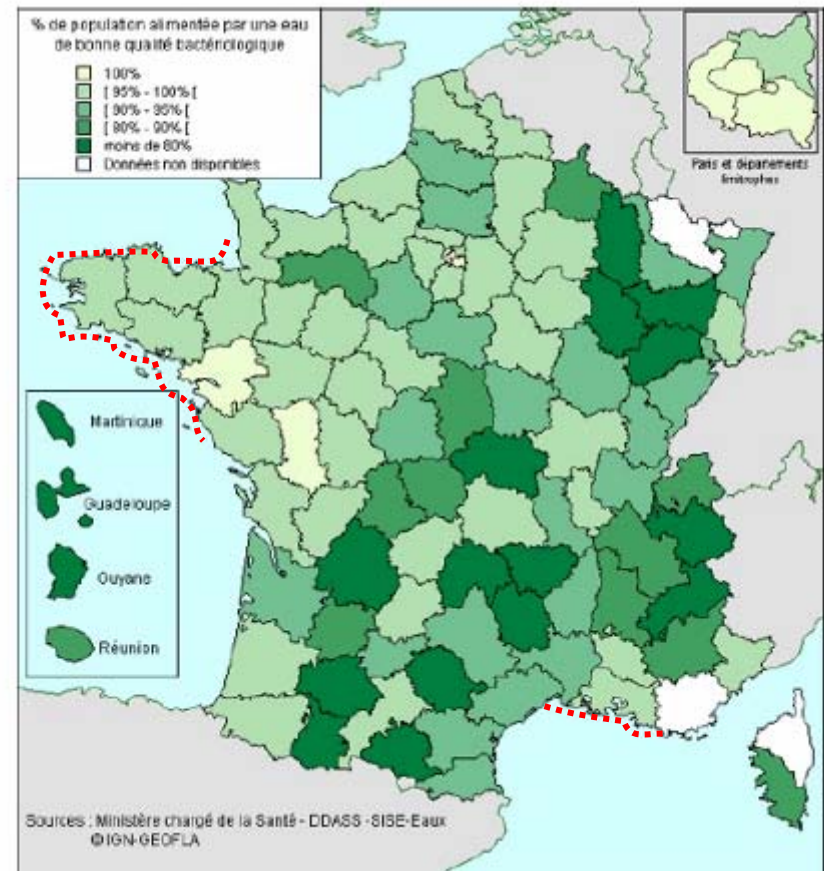


NO₃⁻ concentration in water



Microbial quality of drinkable water (2002) : more problems in mountains (more range lands, slopes, less water treatment)

Light green : 100 % good quality
Dark green : < 80% good quality



↘ of organic load (N directive)
Level off or slow decrease in western waters

Objectives	criteria	Risky agricultural practices
Chemical	Nitrate	Intensive use/ fertilization/grazing
	Phosphorus	Intensive/ fertilization/grazing
	COD	Intensive/extensive/
	Micro-pollutants Heavy metals	Sludges or animal issues spreading
Biological	Phyto-zoo Bio-indicators	Intensive/extensive/grazing
	Fish	Intensive/extensive/grazing
Micro-Biological	E. coli	grazing, stream access
Others	Drugs residues	few documented

Water Framework Directive

Water Bathing Directive

National regulation : N and P Regulations

- **Limitations** : maximum 170 organic N / ha AA / yr ; in ZAC : Upper limits 210 Kg total N.ha⁻¹.year⁻¹ (→ 170, 140 ?..)
- **Equilibrium of N Fertilization and recording** at farm level (*control*)
- **Good use of animal manures** : Analysis, Restriction / location & period according to the fertilizer ; Sufficient storage capacity to improve manure use
- **Intercept losses** : Vegetation cover in winter, grass filter strips along rivers

Concerning Phosphorus

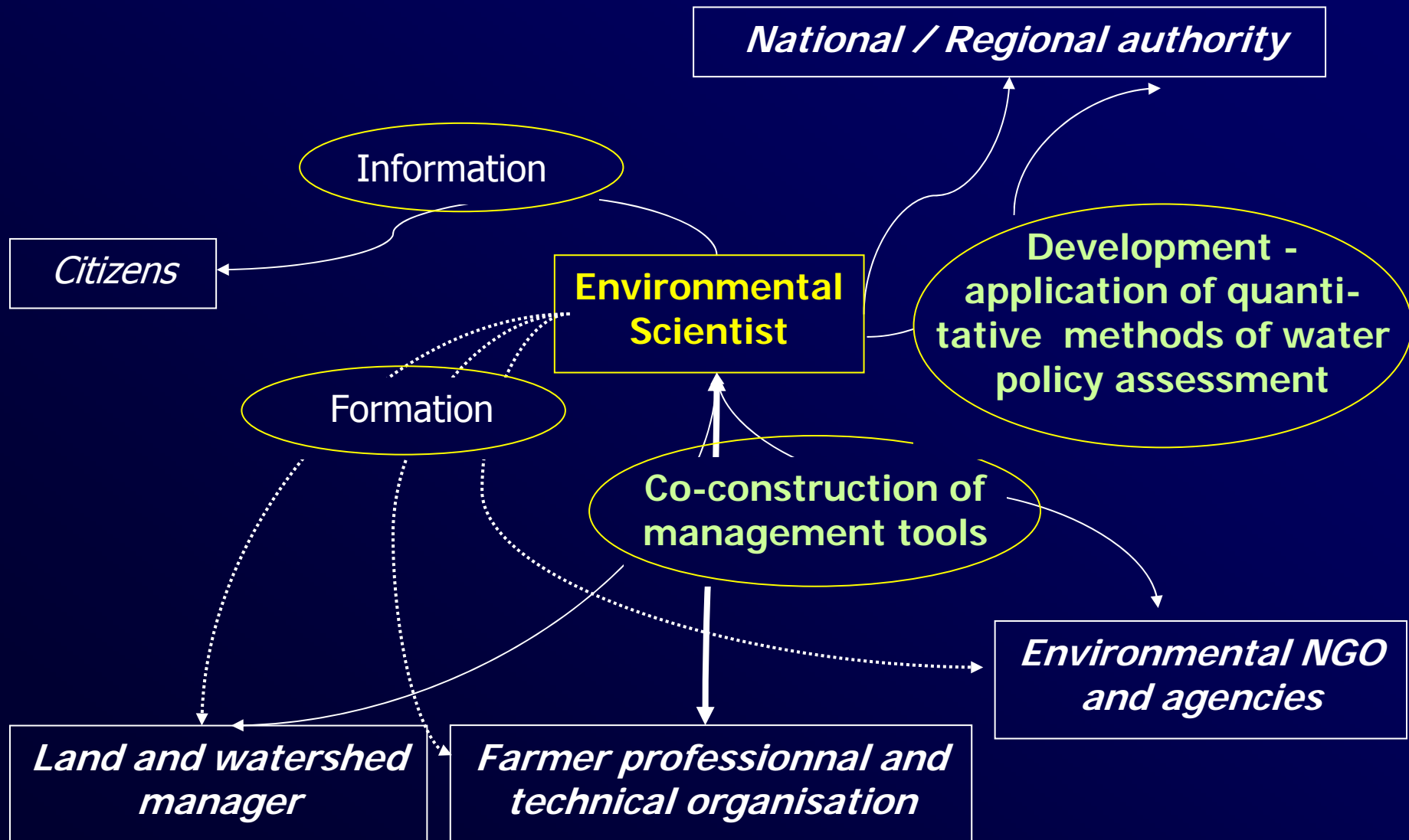
- No P application higher than 100 kg P₂O₅ .ha⁻¹

National legislation expected in the near futur (4th national plan related to the N Directive)

What is discussed :

- Respect of a balanced P fertilisation ?
- Forbidding P starters or mineral P fertilisation, where soil P > threshold

Current relation between environmental scientists and society in the framework of the water policy *(Mérot, 2008)*



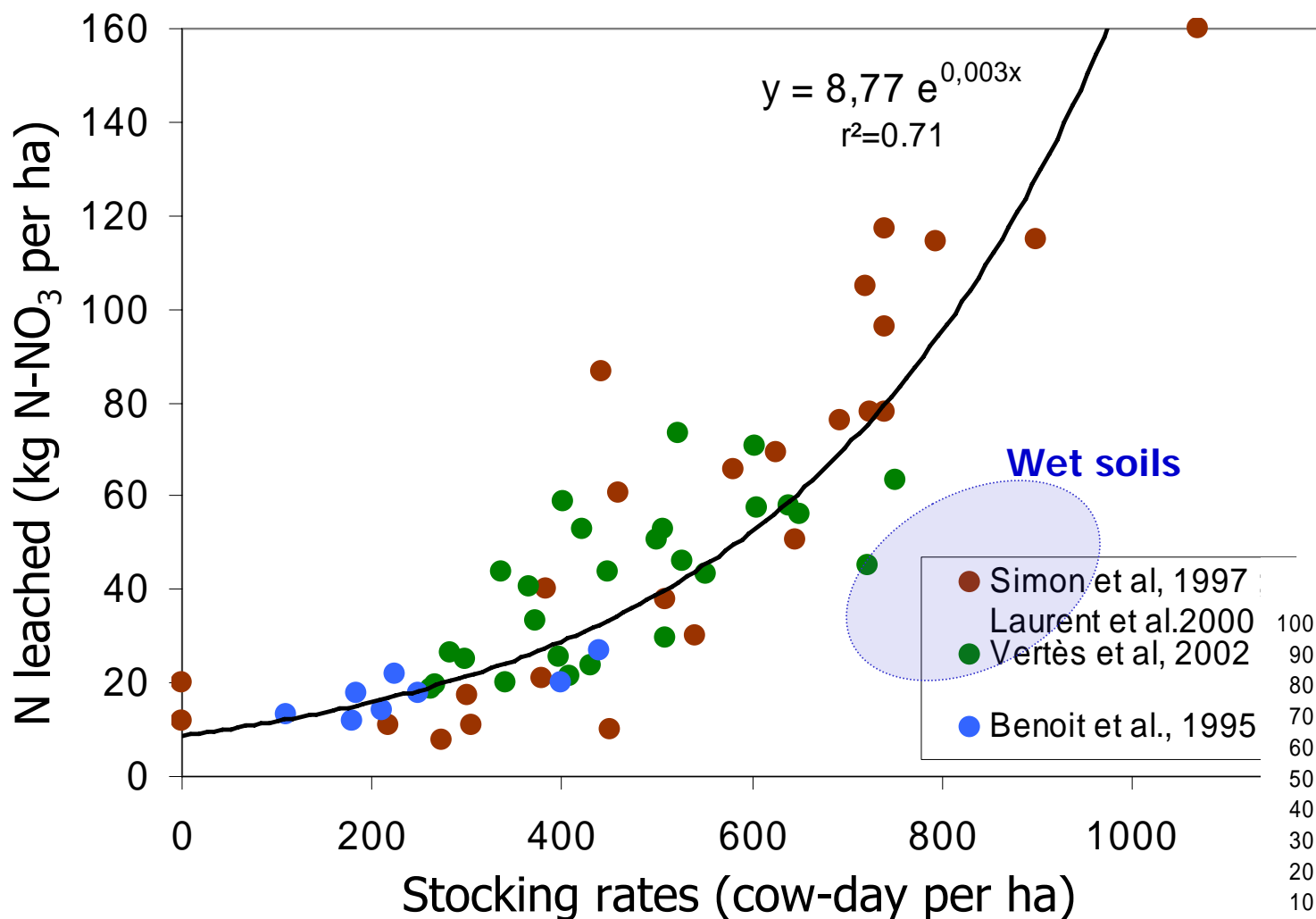
Challenges to respect water quality (WFD)

- Still too high level in nitrate in surface water
 - better understanding and modelling of NO_3^- fluxes, more generally N cycling, in agricultural catchment
 - Sources, spatial variability, transfer time, role of buffer zones (hedges, riparian wetlands, grasslands), gaseous emissions
 - Scaling from small catchments to largest ones
- Increase of dissolved organic matter
 - Origin and dynamic of DOC and DON in surface waters
- Degradation of habitats in aquatic ecosystems, (eutrophication,...)
 - Origin and dynamic of SS, Phosphorus, bacteria ...

Knowledge on processes

- Focus on few processes
 - N
 - P
- Grassland main assets
- Comparison of N, P and bacteria sources and fate

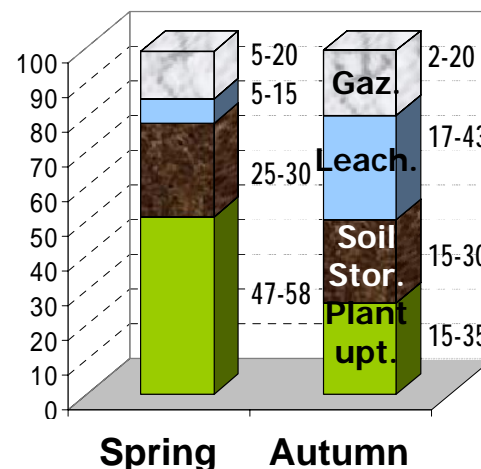
Key points on Nitrate leaching at field scale



Ration,
Milk/cow/day

Soil
climate,...

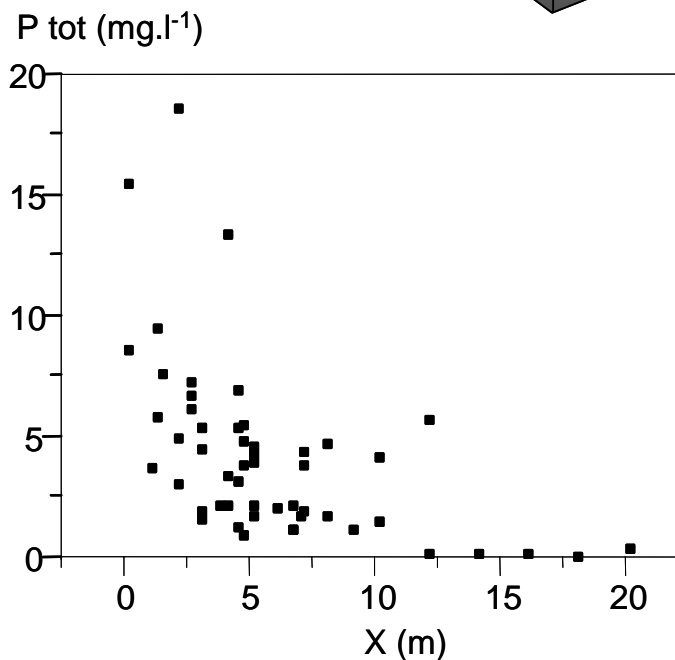
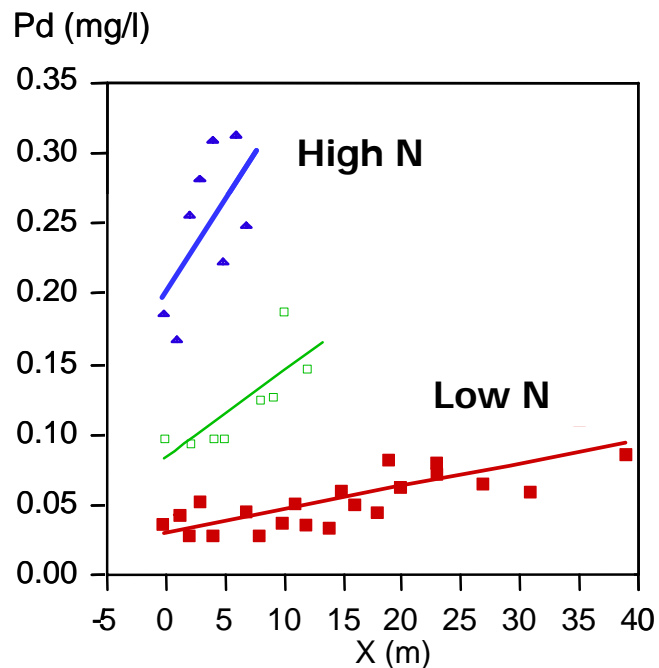
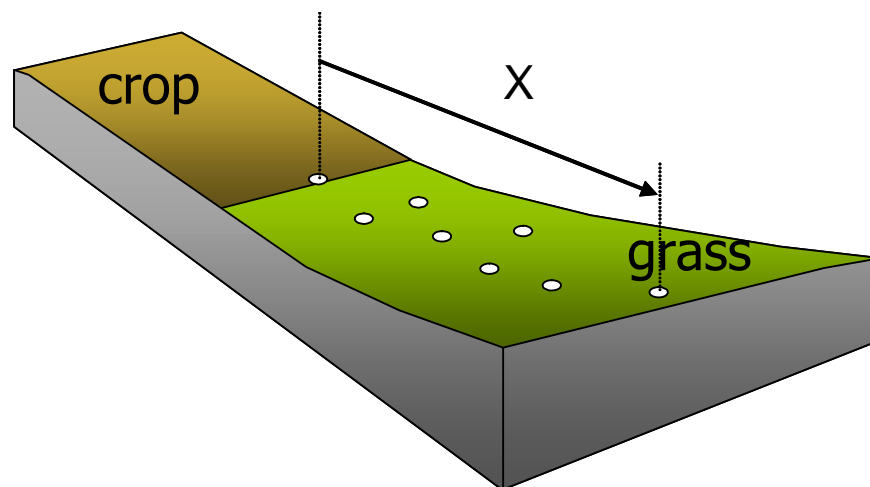
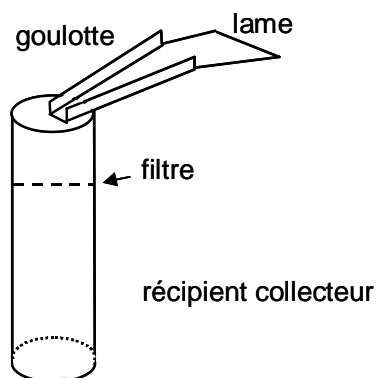
Management



From Decau et al, 2003 ; Vertès et al, 1997 ; Leterme et al, 2003

Each point is the mean of the results during 3 to 6 years

Effects of landscape rugosity on Phosphorus fluxes



Pp \searrow with X
(retention in grassland)

Pp \nearrow with runoff
concentration

Pp with % bare
soil

Pd \nearrow with fertilisation

from Trevisan et al., 2001

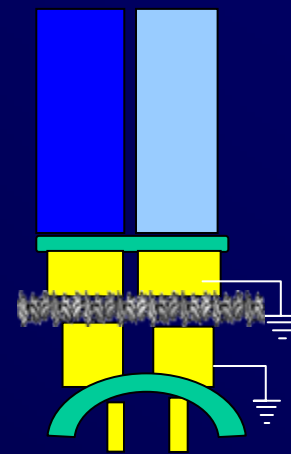
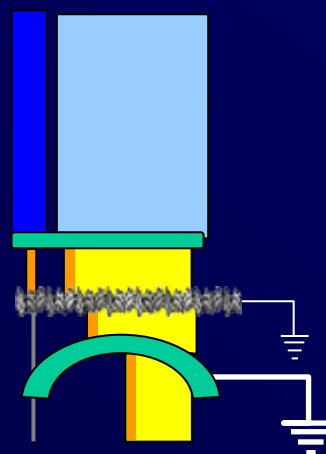
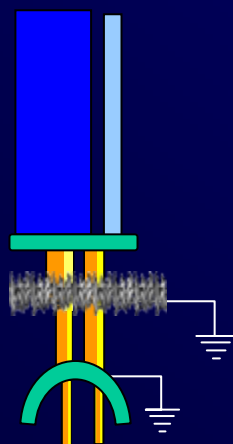
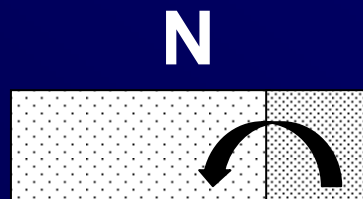
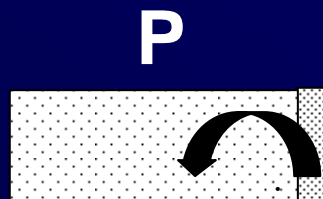
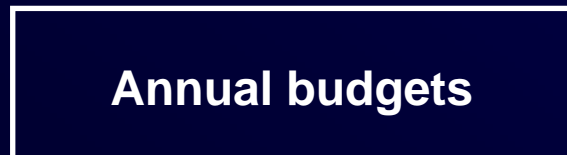
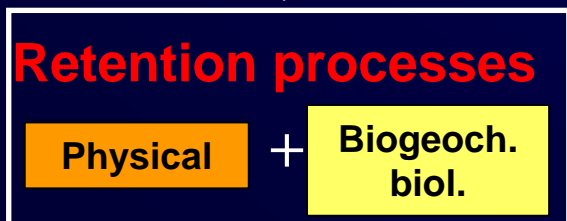
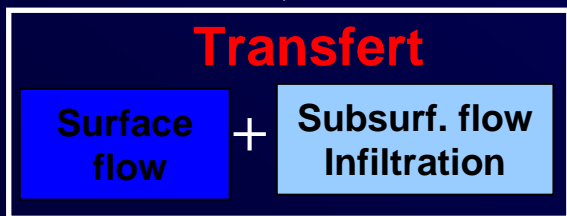
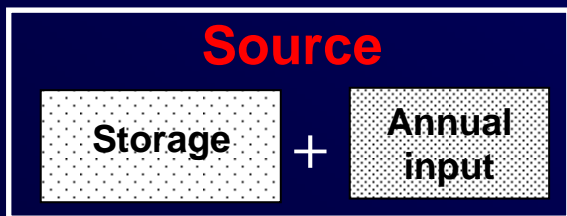
Main grasslands assets

	Water quality	Erosion	OM storage
Annual forages (maize, IRG 6 months.....)	-/+	-/+	-/+
Grasslands 2-5 yrs High N	+	+ / ++	+ / ++
Low N	+ / ++		
Grasslands 6-10 yrs High N	++	+++	++ / +++
Low N	+++		
Permanent grasslands, high ecological value pastures	+ / +++	+++	+++

from Barbin et al., 2007, Dossier Special Prairies IE

Comparison / N, P, bacteria in agro-ecosystems

from Durand, P., Merot, P., Gascuel-Oudou, 2005 - modified



Grass strip

Tree hedge

Riparian +in stream

emissions/input < 5%
 $\sigma(\text{emissions}) > 100\%$
 Flux \neq f(stock)

> 10%
 $\sim 100\%$
 = f(stock)

< 1%
 $> 100\%$
 \neq f(stock)

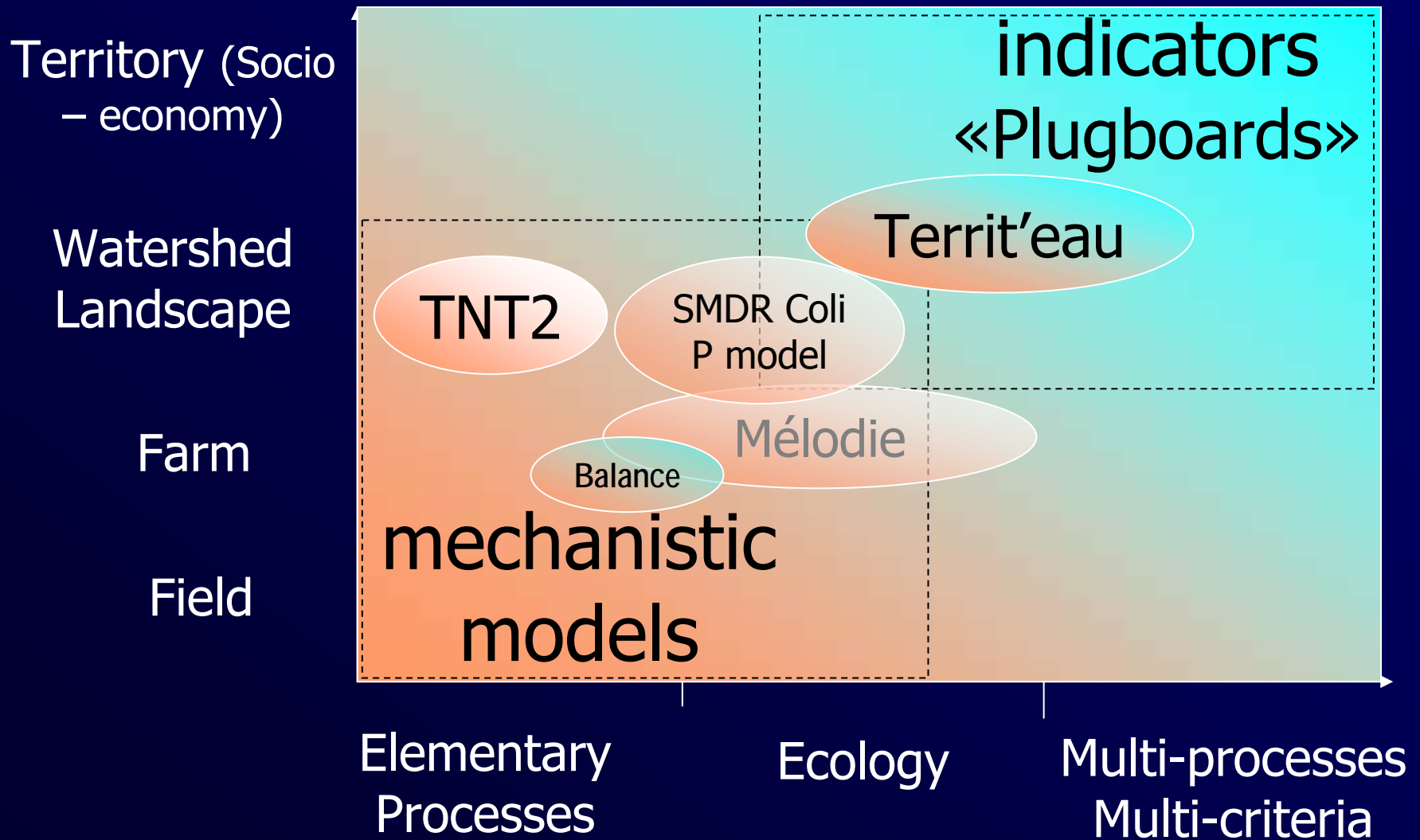
erodibility connectivity
 Sustainability ?

hydrological setting biological activity
 Variability ? Air ?

critical sources / runoff biological activity
 episodic

From diagnostic to evaluation

Which methods and tools are available ?



BALANCES**Inputs**

—

Outputs

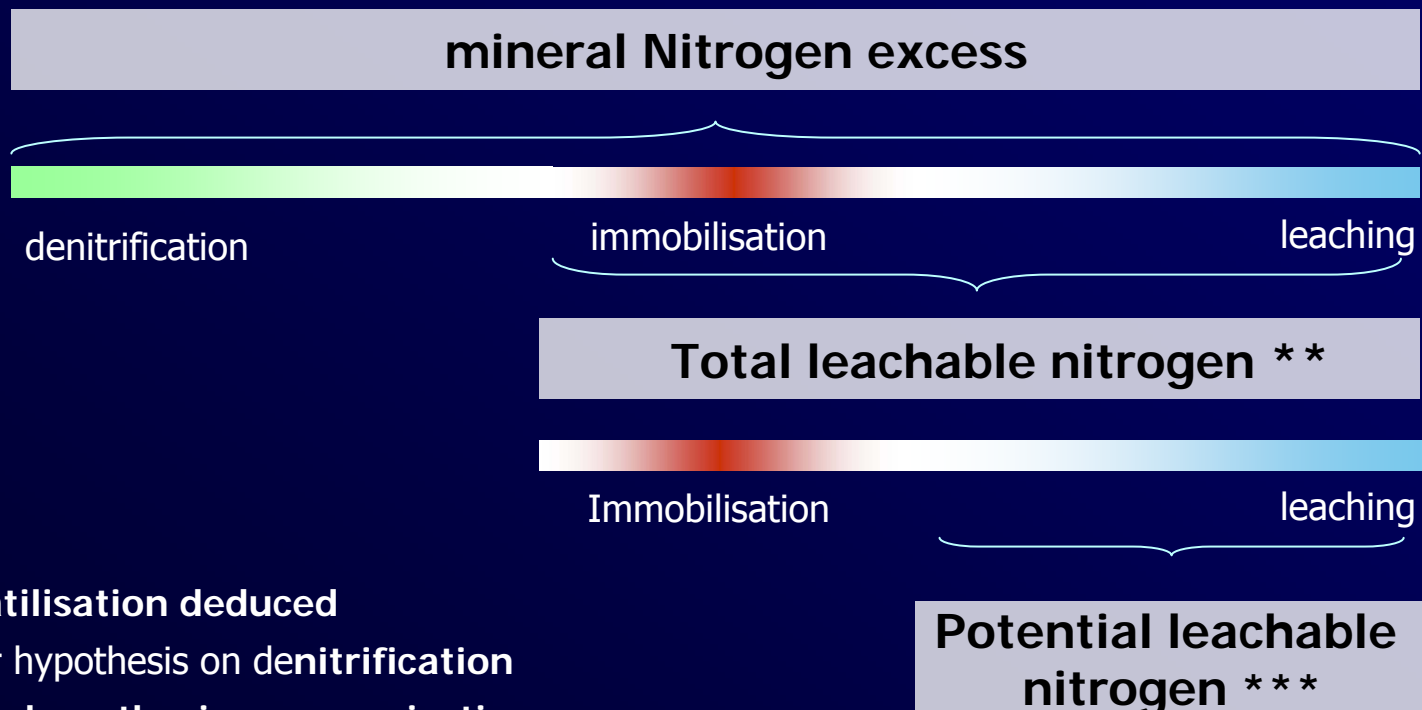
Chemical and organic fertilizers*,
 fixation, manures*, OM mineralisation
 Rainfall deposition

Grass produced (t DM/ha x %N)

=

Ncycle (*Scholefield et al, 1991*)

AZOPAT (*Decau et al., 1997*)



* volatilisation deduced

** after hypothesis on denitrification

*** after hypothesis on organisation

similar methods : Animal N balance (*Delaby et al., 1997*)

Farm gate N (P) balance (*Simon et al, 1992*) + **LCA** (*Payraudeau et al., 2003*)

Nitrate fluxes in watershed (agricultural practices, buffer zones)

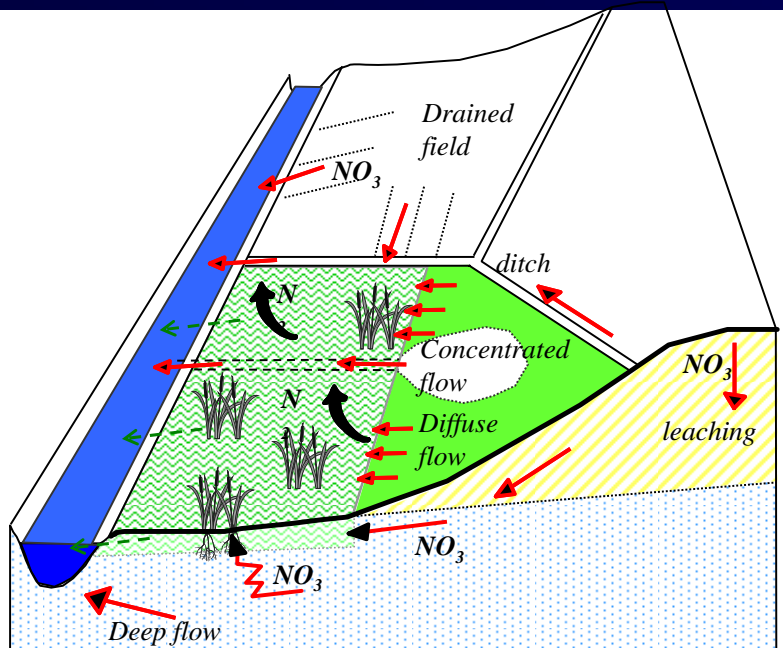
- 1° N storage in shallow ground water is due to the past period
- 2° The response of the catchment includes past and current mitigation options
- 3° Modelling is required to separate the effects and predict the trends

TNT2

Coupling hydrological model TNT with plant-soil model STICS

Distributed model, per pixel → soil occupation, agricultural practices, soil and climate data...

Applied to evaluate the effect of Agricultural practices, Farming system, Wetlands, Hedge rows (Viaud et al., 2006)



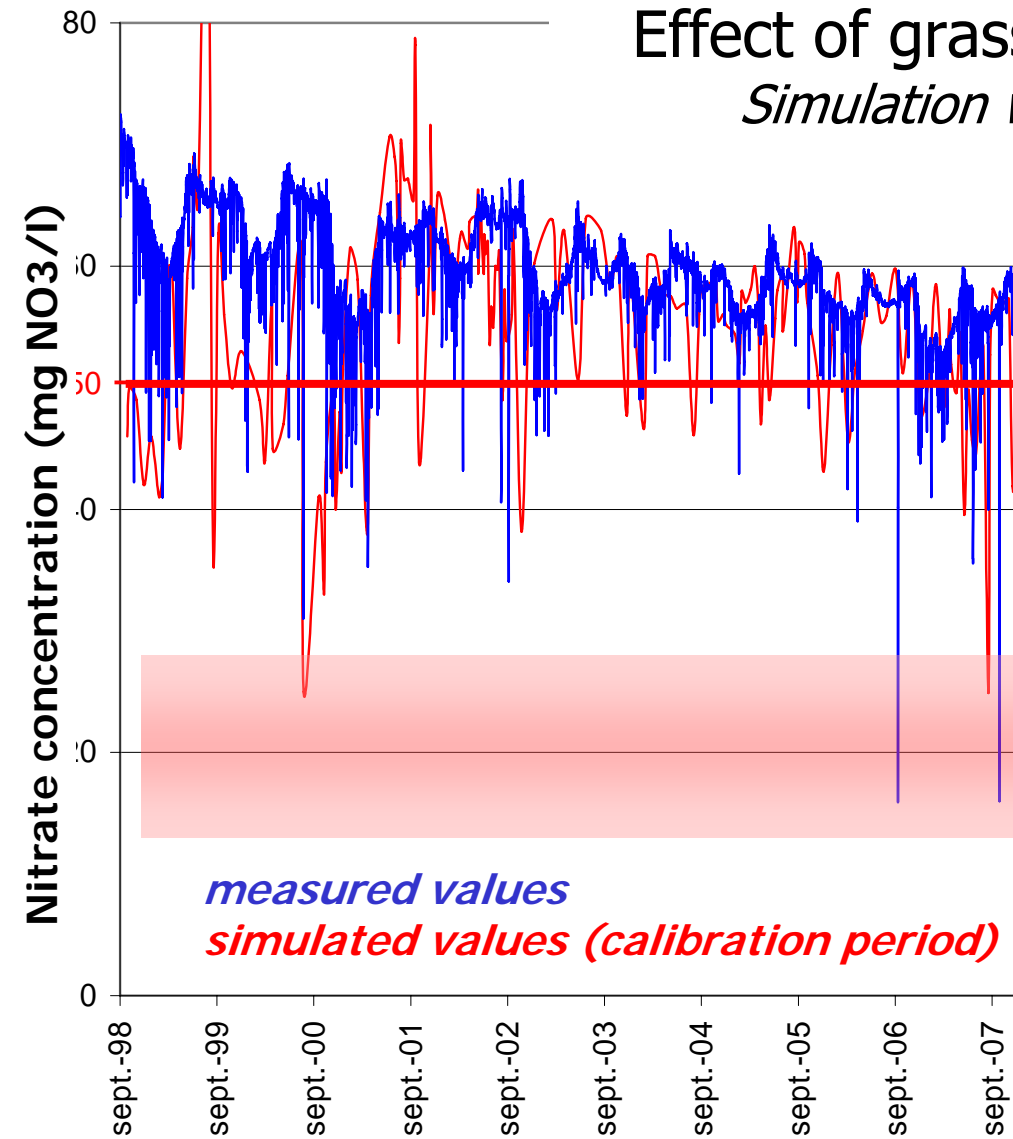
Topographic based Nitrogen Transfer (TNT)

Beaujouan et al., 2001, *Ecol. Modelling*
Beaujouan et al., 2002, *Hydrol. processes*

Involved in NitroEurope, European litigation about Nitrates, to test scenarii

Effect of grasslands on nitrate concentration

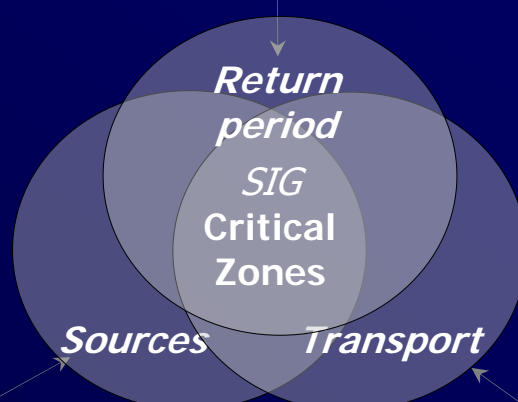
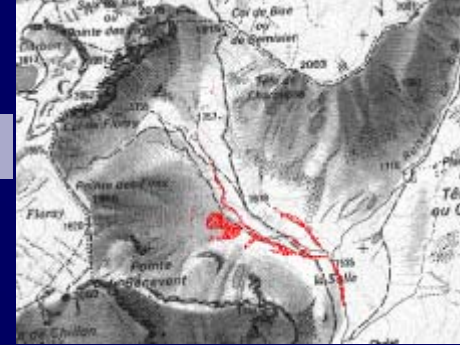
*Simulation with TNT2 model in the Echelles river
from Durand et al., 2008*



Statistical analyses of meteorological data

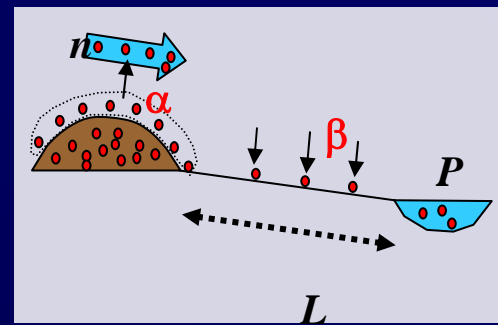
(T= 5 yrs)

T=10 yrs



Bacteria Emission

Bacteria Retention



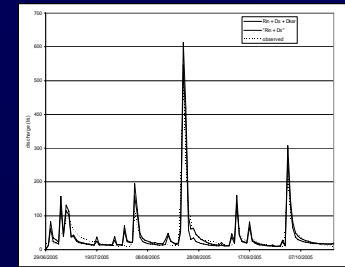
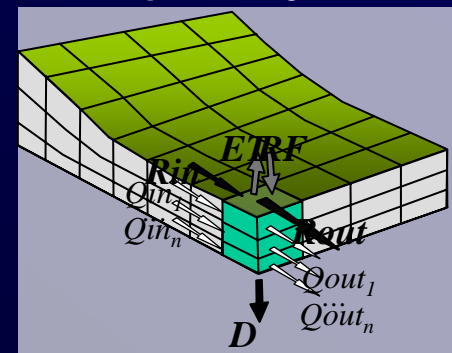
inverse Analyse

Observed bacterian fluxes

Stocks of movable bacteria

dung location

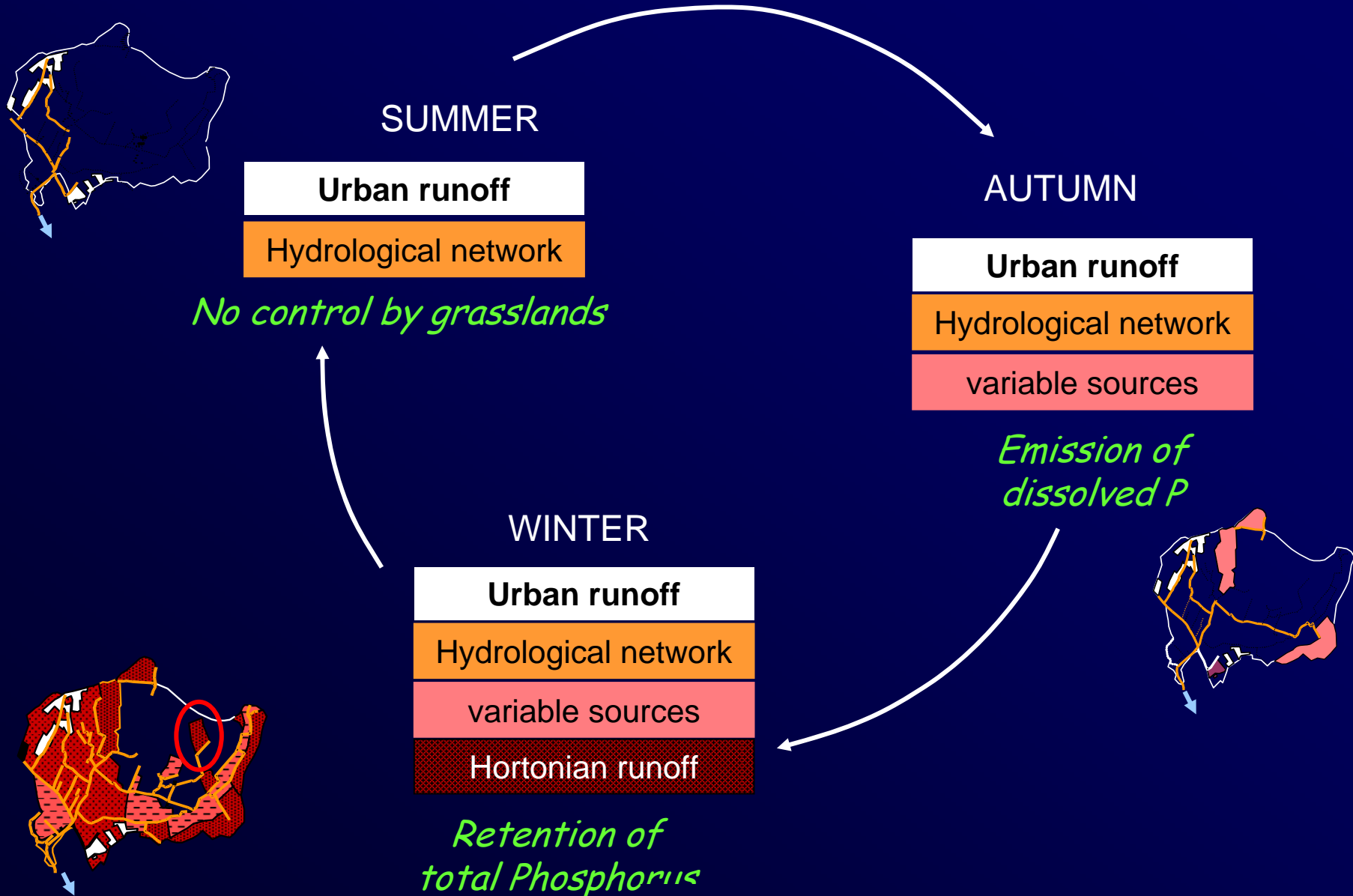
Runoff (amount - flow pathways)



E. coli : Critical sources areas

from Trévisan, 2008

Phosphorus mobilisation, active pools and role of grasslands



Territ'eau : Spatial management of agricultural activities and landscape features for water protection



Transfer the scientific knowledge on the hydro-chemical functioning of catchment http://agro-transfert-bretagne.univ-rennes1.fr/Territ_eau/



Territ'eau
Framework

Human and social environment

Module 1

General characteristics
50 -100 km²

Module 2

Landscape feature analysis
Key source areas 10 km²
Functional typology of wetlands,
Merot et., 2006.

Agricultural practices, pressure

Modules 3-4-5

N, P, pesticides - 10 km²

Mitigation options

Module 6

Innovative experiences

**3 axes
mitigation
options**

Transfer

Raisoning
Optimize

System

Indicators : Multicriteria environmental evaluation of fodder systems, see also LCA....

	Stocks based systems	Grass/maize systems	Grazing systems
% maize/FA	50 - 60	20 - 30	< 20
t DM stocks/cow	4 - 5	2,5 - 3,5	2 - 2,5
Stocking rates (LSU/ha FA)	1,6 - 2	1,6 - 1,8	1,4 - 1,8
N balance (kg N/ha AA)	80 - 120	80 - 100	60 - 80
N leaching (kg/ha AA)	50 - 70	40 - 60	30 - 40
P transfers (kg/ha AA)	++	+	+
Pesticides use	++	+	-
Bacterial contamination	+	+	++
Energy use (MJ/kg milk)	4	3	2.5
C storage in soils	+	++	+++
Biodiversity and landscape	+	++	+++

CONCLUSIONS

- Lot of knowledge on nitrate, phosphorus, SS, bacteria sources and transfer
- Several models at field, farm, watershed scale
 - But often difficult to use out of their contexts (parameters)
 - Not easy to use by partners (non researchers)
- Lot of progress on environmental evaluation
 - Pluri-annual (rotations)
 - Inserted in production systems
 - Multicriteria (avoid pollution swapping)
- Interest of concerted approach to define constraints and innovation capacities

Synthesis : perspectives to solve problems in several contexts / grasslands

	Water quality		
	N	P	E. Coli
	Intensive	Intensive/extensive	(25% uplands)
Intensive	<p>Control nutrient balances</p> <p>Grazing /stocking rates</p> <p>Evolution of production systems</p> <p>Place and date of spreading</p> <p>Definition of thresholds / ecosystems health</p> <p>Landscape management/buffer zones</p>		
Extensive	<p>Control contributive areas</p> <p>Grazing ingeenerny/ infrastructure</p>		

Still some work to do....

- To couple farm and watershed scale (decrease sources and transfer considering farms constraints)
- To Develop transdisciplinary approaches and co-built tools (decision support with end-users, scenario building with farmers)
- Validation and improvement in modelling
- To develop results vs mean based approaches
 - develop decision support tools
 - adapt them to the local conditions
- Use multicriteria analysis (and meta-analysis)

Thanks for your attention

