

Enhanced efficiency fertilisers for agricultural sustainability and environmental quality in Australia

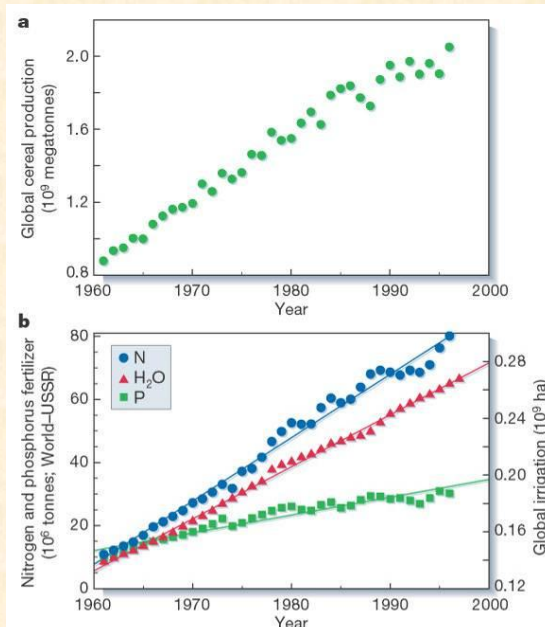
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Why Use EEFs?

Irrigation and fertiliser use (N and P) are essential for:

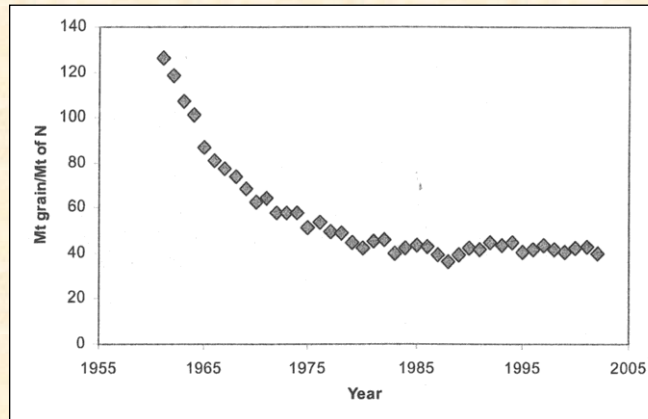
- **Achieving high yields/profit** (developed countries)
- **Food security** (developing countries)



[Source: Tilman et al, 2002. Nature]

- Efficiency of N fertiliser has declined and is low

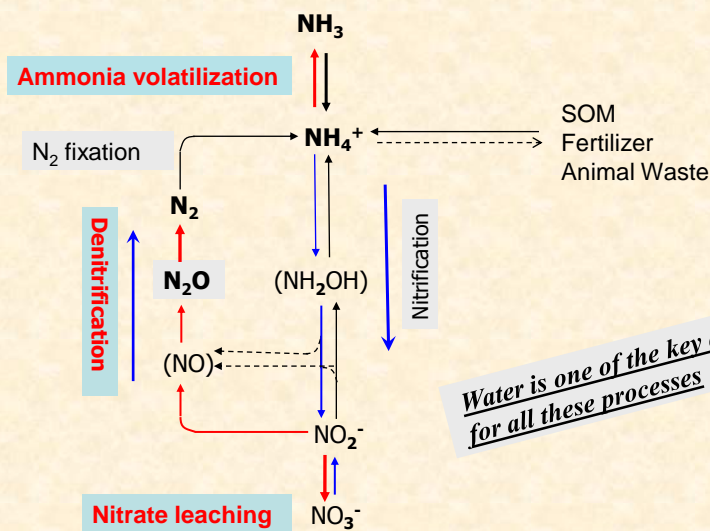
- Australia: NUE 6-59%, average < 40% (Chen *et al.* 2008)

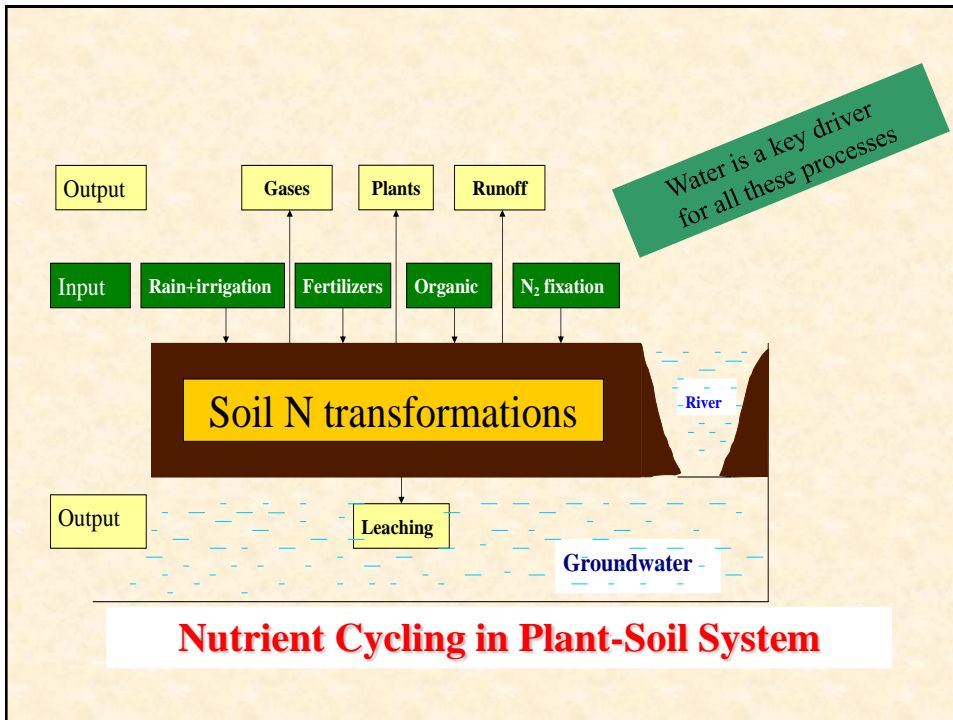


Metric tons of grain produced per metric ton of fertilizer N applied in the world (1961-2002)

[Source: Raun and Schepers, 2008, Nitrogen in Agricultural Systems]

N-transformations in soil





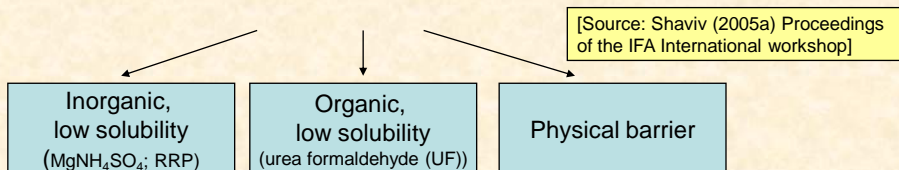
Why use EEFs?

- Environmental impact, eutrophication
- Mitigation of GHG (N₂O) and indirect GHG (NH₃) emissions
- Increasing cost of N fertiliser

Enhanced Efficiency Fertiliser (EEF)

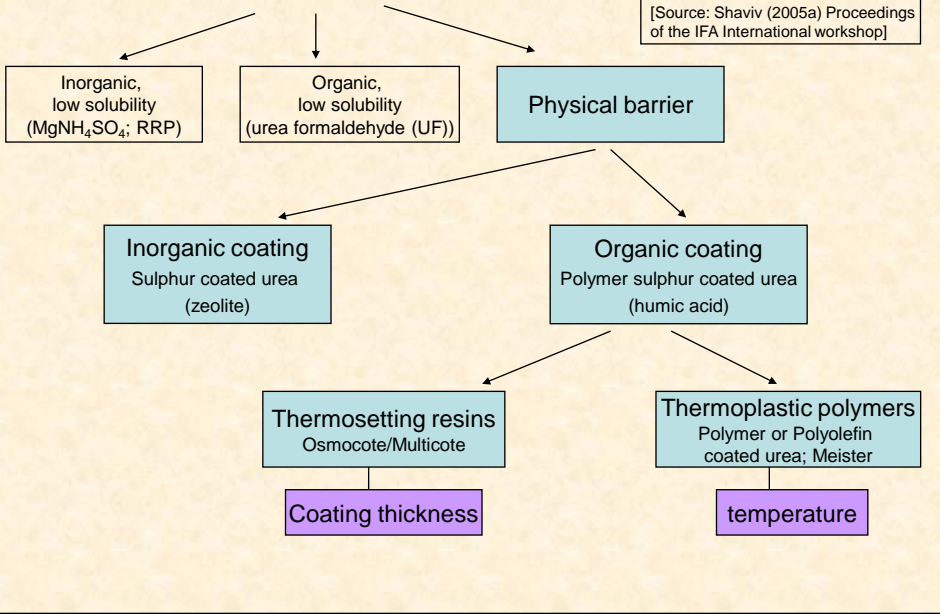
- Controlled (slow) release fertilisers (CRFs)
- Urease Inhibitors
- Nitrification Inhibitors

Controlled release fertiliser



Controlled release fertiliser

[Source: Shaviv (2005a) Proceedings of the IFA International workshop]



Coated CRFs

Release patterns

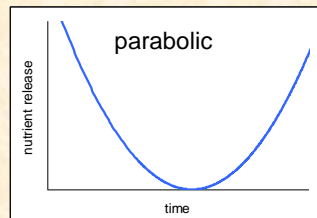
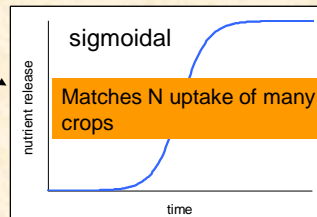
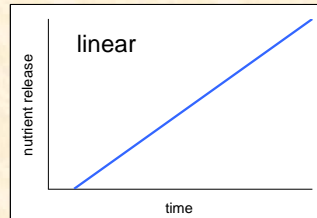
- Long or short term
- Degrees of sophistication (eg. computer simulations)

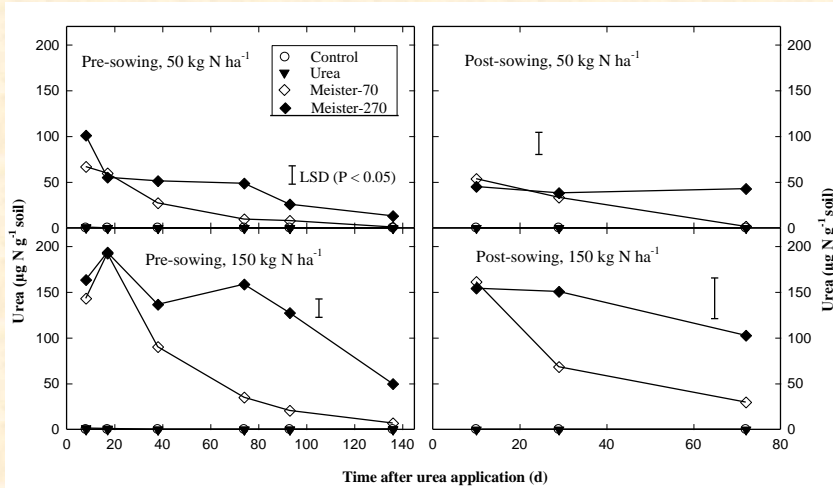
Benefits/Problems

- Matches nutrient requirements (sometimes)
- Not fully utilised (sometimes) – N loss

Uses

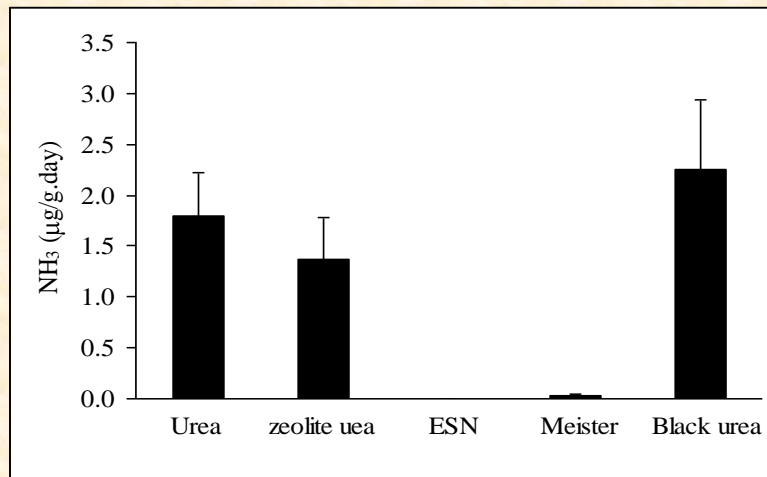
- Largely horticultural
- 10% in agriculture (cost)





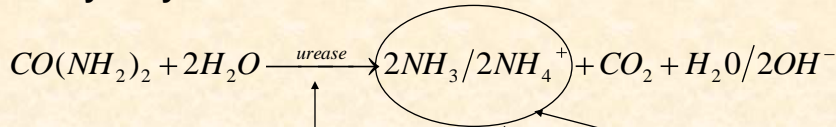
Urea (0 - 0.30 m soil) at two rates and two times of application of urea, polyolefin-coated urea (Meister) (Chen *et al* 2008).

Comparative NH₃ losses of the controlled release fertilizers from a wheat cropping vertosol (western Victoria, Australia) at 50% WFPS and 25°C (2nd day of the incubation).



Urease inhibitors

Urea hydrolysis



Urease inhibitor

pH granule

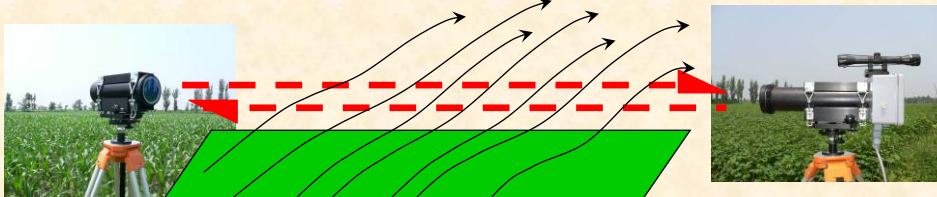
NH₃ reported losses
0 to >50% of applied N
Eg. pasture, Aus: 20%
[Prasertsak, et al. 2001, Eckard et al, 2003]

- Role: To
 - retain N in Urea form for longer
 - reduce NH₃ volatilisation

Open path laser/FTIR s to measure NH₃

Reflector

OP Laser



NH₃ emissions

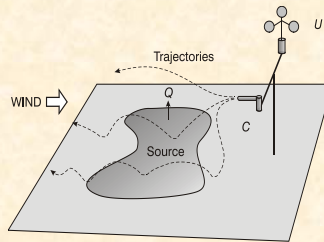
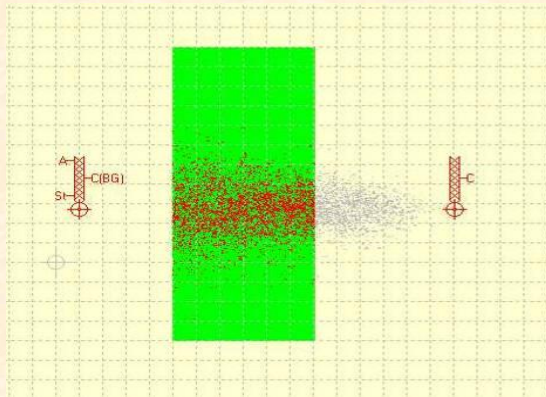
Wind direction

- Measures line-average concentration

- Detection limit 10 ppb for 100 m path length

- Battery or mains powered

Turning concentration measurements into emission flux -- backward Lagrangian stochastic (bLS) dispersion analysis (WindTrax)



Urease inhibitors

Class	Example inhibitor
react with sulfhydryl group	hydroquinone (HQ)
complex with Ni	acetohydroxamate (AHA)
structural analogue of urea	N-(n-butyl) phosphoric triamide (NBPT)
	cyclohexylphosphoric triamide (CHPT)
	phenylphosphorodiamidate (PPD)
crop protection chemicals	Diazinon
natural products	Neem, coal tar

[Source: Medina and Radel (1988) Mechanisms of urease inhibition]

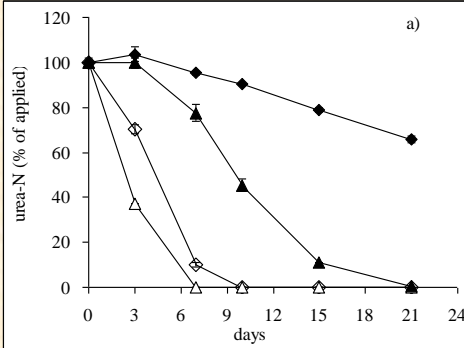
NBPT: Reported effects on NH₃ losses

Crop, Country	Reduction (%) in NH ₃	Reference
Pasture (cores), NZ	27 (urea) 23 (urine)	Singh et al., 2004
Sunflower, Spain	42	Sanz-Cobena et al., 2008
Grasslands, Ireland	50	Watson et al., 1994
Soil (cores), UK	61-80	Watson et al., 2008
Soil, Canada	82-96 (peak)	Rawluck et al., 2001

Effect of urease inhibitor in wheat cropping soil,
incubation exp:

◇ urea (15°C), △ (25°C)

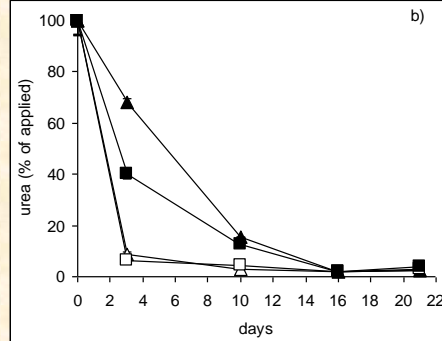
◆ urea+NBPT(15°C), ▲ urea+NBPT (25°C)



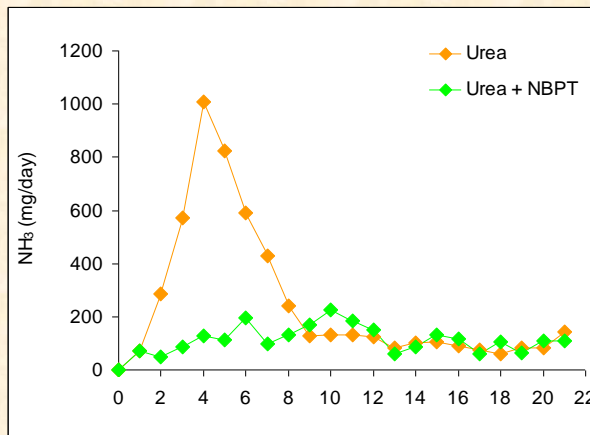
Effect of urease inhibitor in sugarcane trash blanket, incubation exp:

△ urea (25°C), □ (45°C)

▲ urea+NBPT(25°C), ■ urea+NBPT (45°C)



Reduction in NH₃ emissions from sugarcane trash blanket, 25°C



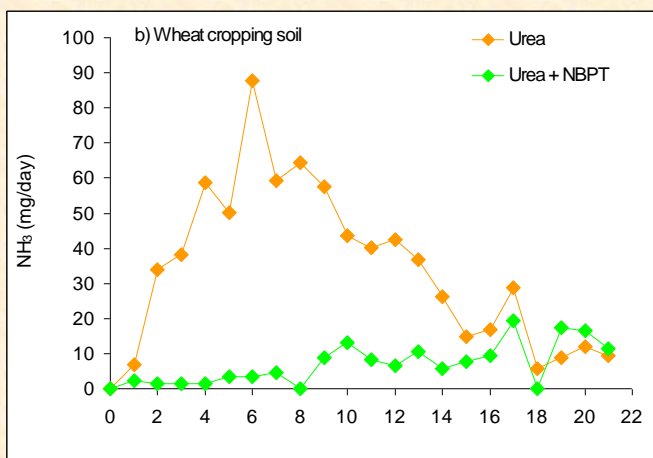
Urea :

- 78% urea-¹⁵N volatilised as NH₃ over 21 days

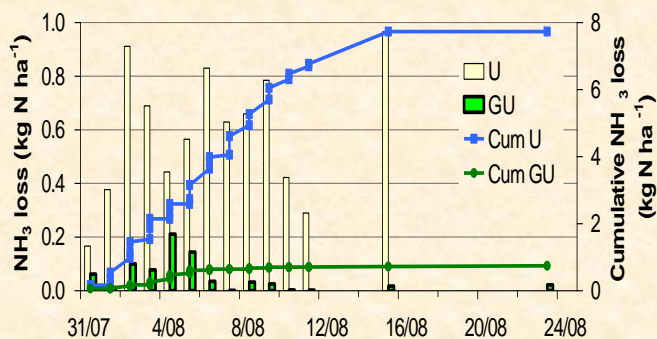
Urea + NBPT:

- 54% reduction in NH₃ over 21 days

Reduction in NH₃ emissions from wheat cropping soil



Urea + NBPT:
 • 79% reduction
 in NH₃ over 21
 days (clay loam, pH 7.8)
 (at 15°C)



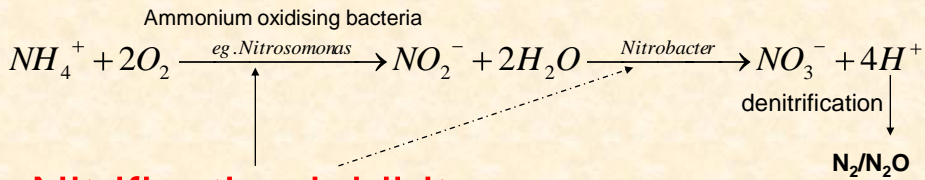
NH₃ losses measured in the field on a wheat soil from the Wimmera, western Victoria, using micrometeorological technique:

7.7 kg N ha⁻¹ (9.7% of applied N) in urea

0.8 kg N ha⁻¹ (1.0% applied N) for the green urea (containing NBPT)

Nitrification inhibitors

Nitrification



Nitrification inhibitor

- Role: To
 - retain N in NH_4^+ form for longer
 - reduce NO_3^- leaching losses
 - reduce N_2O emissions

Nitrification inhibitors

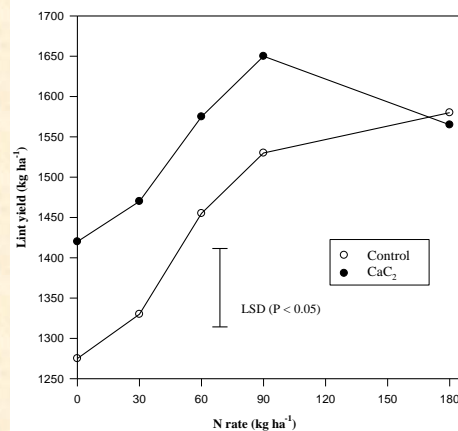
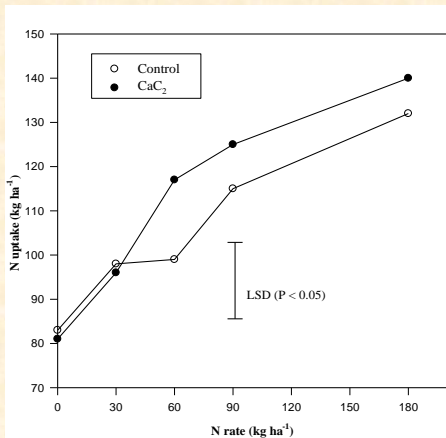
Compound	Name	Comments
Nitrapyrin	N-serve	volatile
Dicyandiamide	DCD	commercially available
3, 4-dimethylpyrazole phosphate	DMPP	commercially available with UAN or Urea
Etridiazole	Terrazole Dwell	liquid
2EP (2-ethynpyridine)		effective but costly
Neem cake/oil	-	limited studies
Acetylene	-	gas

Nitrification inhibitors: Reported effects

Compound	Crop, Country	N loss reduction (% of control)		Reference
		N ₂ O	NO ₃ ⁻ leaching loss	
N-serve	Corn, USA	51	16	Wolt, 2004
DCD	Pasture, NZ	73-82 (urine)	42 (spring) 76 (autumn)	Di and Cameron, 2002, 2006;
	Pasture, NZ	54 (urine)	47 (winter-spring)	Smith et al., 2008
	Barley/ Wheat, Germany	26	23	Weiske et al., 2001
DMPP	Rice/ rape, China	-	45-57	Hua et al., 2008
	Barley/ Wheat, Germany	49	23	Weiske et al., 2001

Effect of coated CaC₂ on N recovery and cotton yield

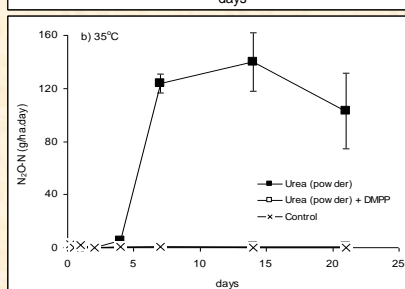
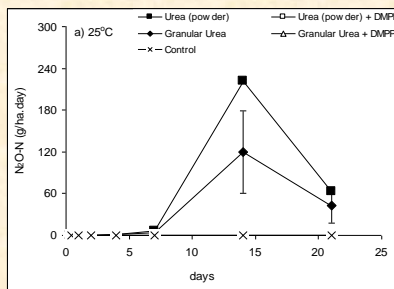
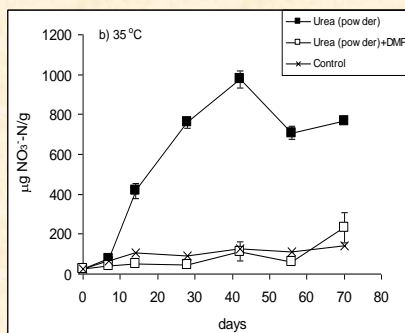
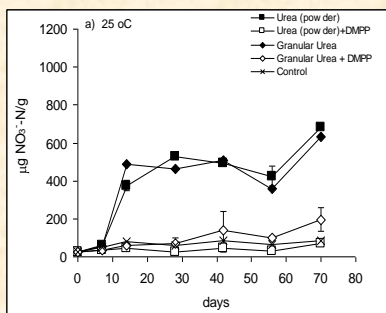
(Freney *et al*, 1993)



Recovery (%) of ^{15}N -labelled urea added to microplots with and without nitrification inhibitors (Chen *et al.*, 1994)

Treatment	Plant	Soil	Total
Control	29.4	27.8	57.2
Nitrapyrin	36.7	37.0	73.7
Wax coated CaC_2	35.4	42.7	78.1
PA	34.0	36.0	70.0
2EP	51.3	40.5	91.8
LSD ($P < 0.05$)	10.6	9.3	11.1

Effect of DMPP on NO_3^- -N and N_2O production in a sugarcane soil in incubation exp, 25°C (a) and 35°C (b)



Balance economic and environmental interests-DSS

- Sustainable high production can not be achieved at the expense of environmental quality
- Need a practical tool which can be used to identify Best Management Practices (BMPs) and incorporates
 - Land use, soil and climate variables,

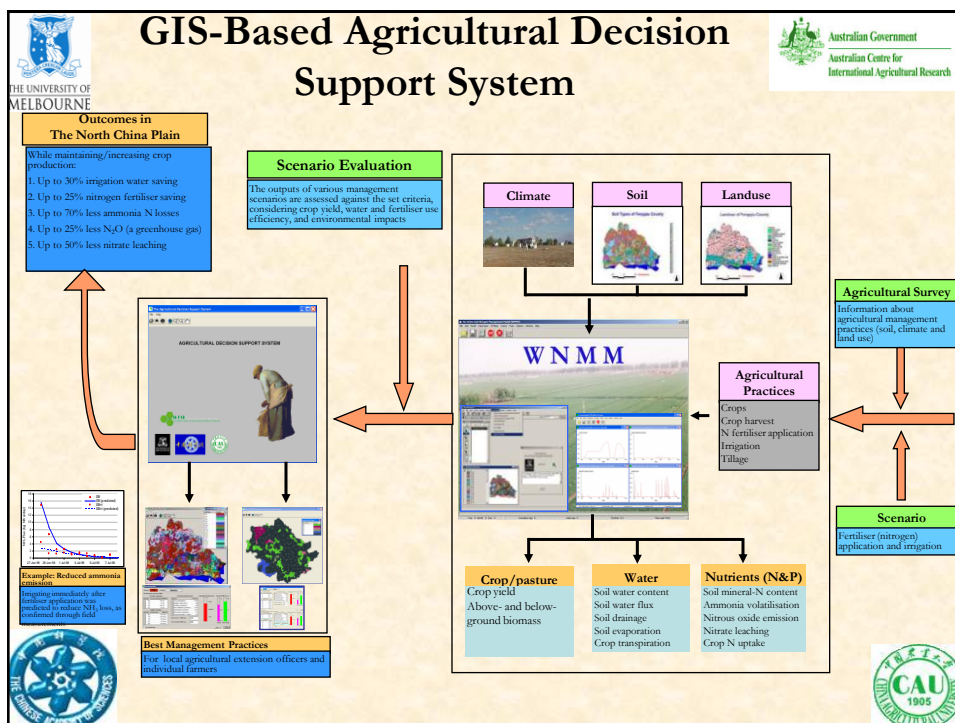
And balances

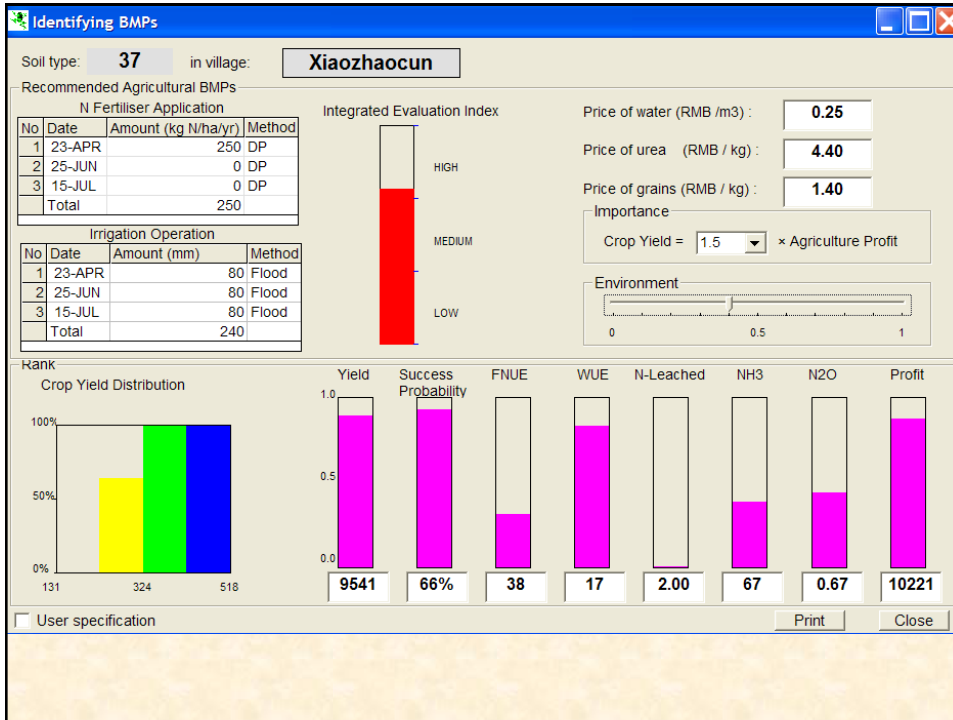
- Economic and environmental interests
- This is the GIS based Agricultural Decision support System (ADDSS) we have developed in China

Location of the exp. sites on the North China Plain (NCP)



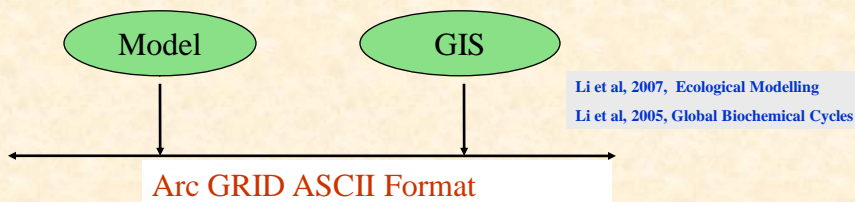
Demonstration of ADDS (Fengqiu)



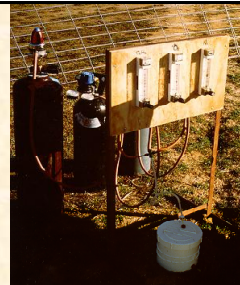
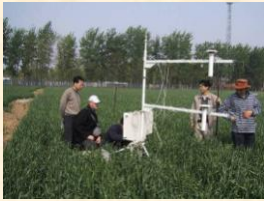
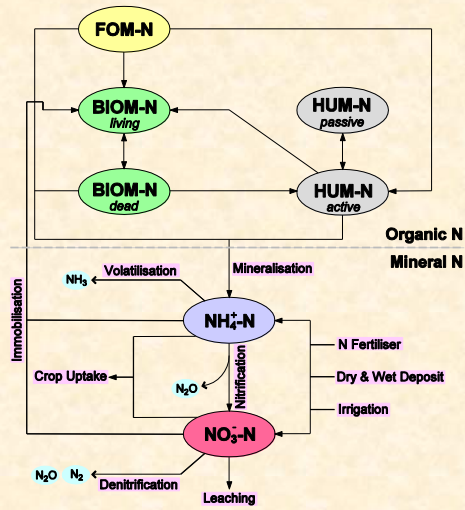


Water and Nitrogen Management Model (WNMM)

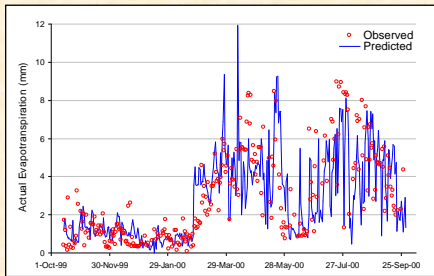
- Simulates water dynamics
- Crop: four crop modules (wheat, maize, rice, pastures and legumes)
- Comprehensive C and N cycling in soil-plant system, including fluxes of CO₂, N₂O, NO_x, N₂ and **NH₃**
- Regional scale simulations, with GIS interface.
- Web-based WNMM (<http://www.wnmm.org>), advanced teaching tool
- Used in China, Australia, USA and Korea



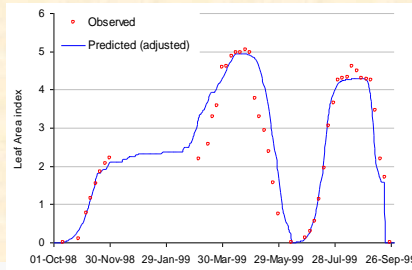
Soil Nitrogen Cycling in WNMM



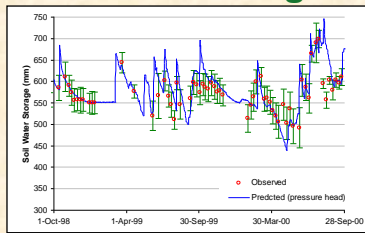
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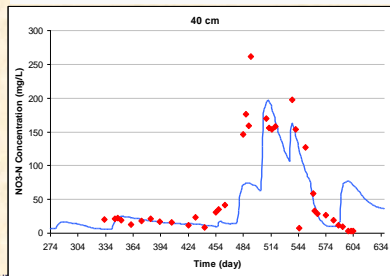
LAI of wheat and maize



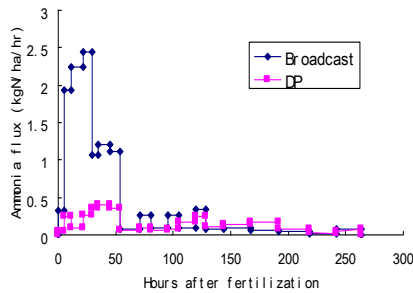
Soil water storage



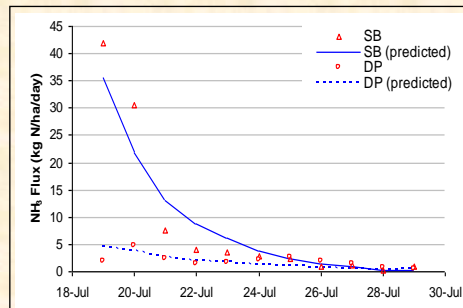
Nitrate



Winter wheat and summer maize rotation in Fengqiu County in the North China Plain



- NH_3 loss accounted for 11-48% of N applied
- The losses were reduced to 11% when urea was applied by deep placement
- Urease inhibitor has great potential

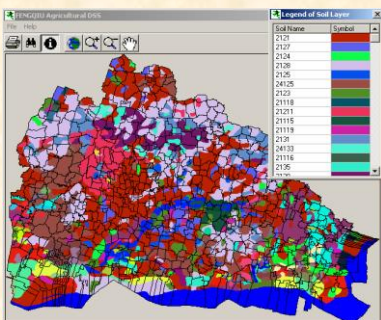


Spatially referenced agricultural decision support system (ADSS)

- Use 'what-if scenarios' functions in WNMM, to identify BMPs, considering economic, environmental and climate variations
- Assembly of ADSS through **embedded-GIS**
- Simple graphically displayed BMPs

Decision support system

- Use 'what-if scenarios' functions in WNMM, to identify BMPs, considering economic, environmental and climate variables
- Assembly of ADSS through embedded- GIS
- Simple graphically displaying BMPs



Knowledge gaps/future directions on EEF

- Comprehensive system-based studies of the impact of EEFs on N cycling and plant growth and interactions of EEFs with other nutrients
- Process-based agroecosystem models to simulate EEF impact
- Decision support tool for fertilizer N management to incorporate EEF

Most beneficial situations

EEF	Conditions
Controlled release fertilisers	Highly intensive systems (Rice, Cotton, horticulture)
Urease inhibitors	<u>Surface applied urea:</u> Pasture (particularly non-irrigated) Rice Rain-fed wheat
Nitrification inhibitors	Wet Coarse soils Mitigation of N ₂ O emissions

Acknowledgement

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