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Lecture III: Organic nitrogen – sources, transformation and transport

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Learning goals of the lecture

After the lecture, you should be able to:

› **... Define dissolved and particulate organic nitrogen**

› **... Describe the sources of dissolved and particulate organic nitrogen in streams**

› **... Create predictions for changes in organic nitrogen amount and sources in streams by land use transformation to agriculture**

› **... Describe processes related to dissolved organic nitrogen in streams**

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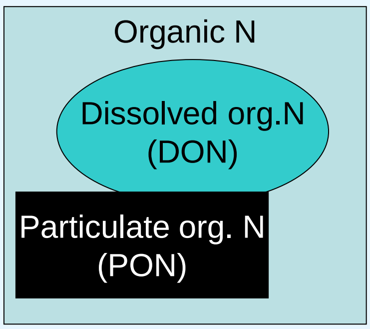
What is organic nitrogen?



<u>How to define organic nitrogen?</u>

Nitrogen bound to a molecule which contains carbon.
&
Which had its origin in living material.

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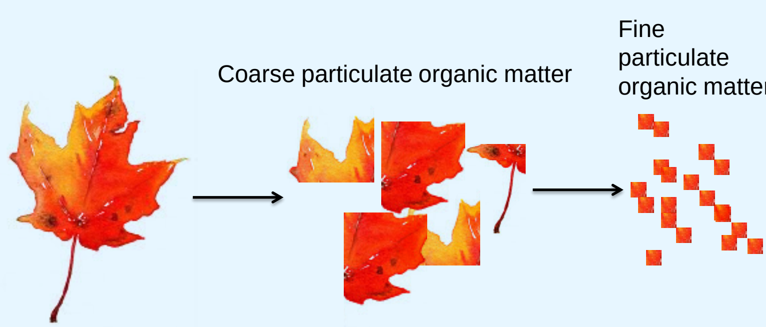
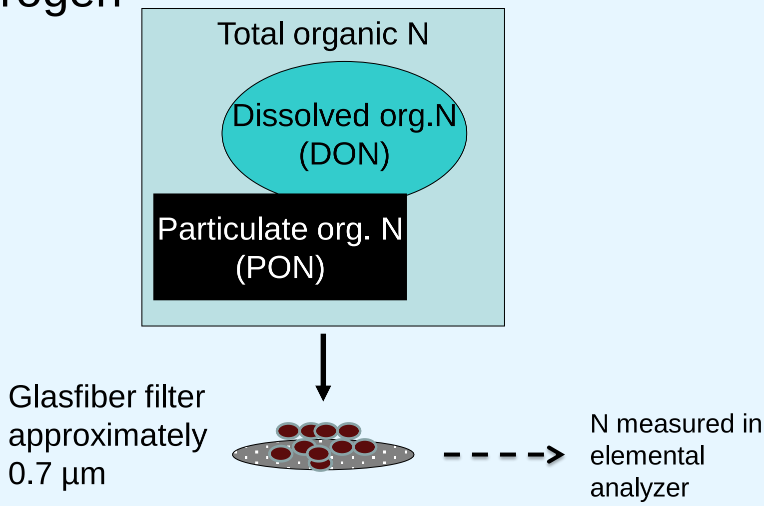
Nutrient Cycling, Modeling and Management from Field to Catchment Scale

What is particulate organic nitrogen?

- **Usually suspended particles of organic matter transported in the water column**
- **Plant remains and plankton**

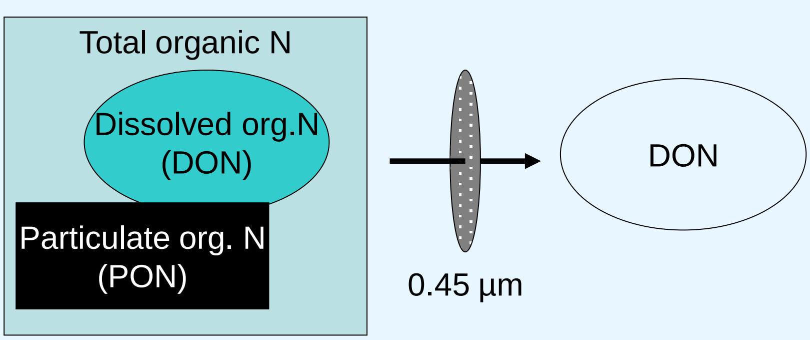


How to measure particulate organic nitrogen



What is dissolved organic nitrogen?

All organic nitrogen < 0.45 µm (in the U.S. it is often all organic nitrogen < 0.7 µm)



How to measure dissolved organic nitrogen

Dissolved organic nitrogen

?

Ammonium

Total dissolved nitrogen

Nitrate

Nitrite

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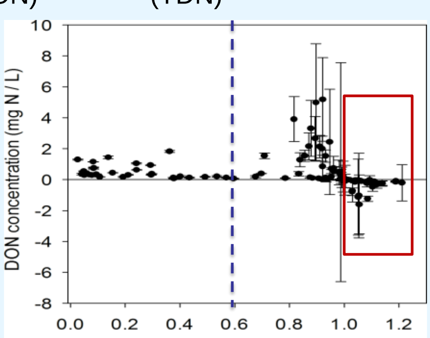
How to measure dissolved organic nitrogen

Dissolved inorganic nitrogen (DIN)

Dissolved organic nitrogen (DON) = Total dissolved nitrogen (TDN) - Nitrate - Nitrite - Ammonium



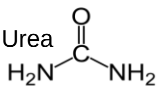
99 sites, N Germany
Error of dissolved organic nitrogen concentration (standard deviation)

Be careful, when you see publications about DON with DIN:TDN ratios > 0.6 (less than 40% of TDN is DON).

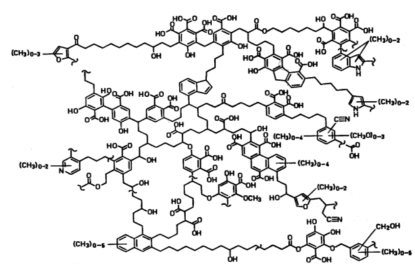
What is dissolved organic nitrogen?

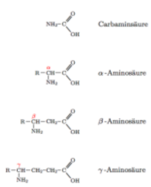
Nucleic acids

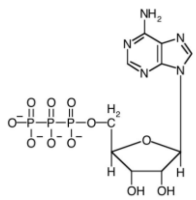
Urea



Humic substances



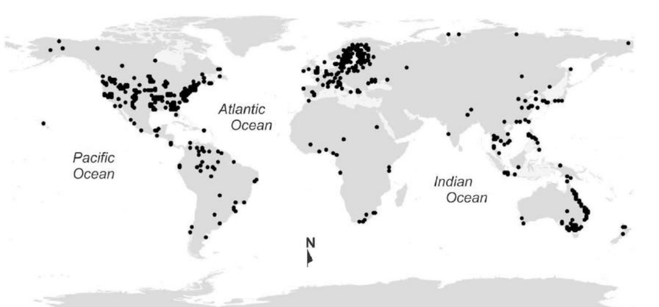




Amino acids,
Dissolved combined amino acids
Proteins,
Amino sugars

Nucleotids:
ATP, GTP
Pyrimidin,
Purin

How much of the total N is organic N?



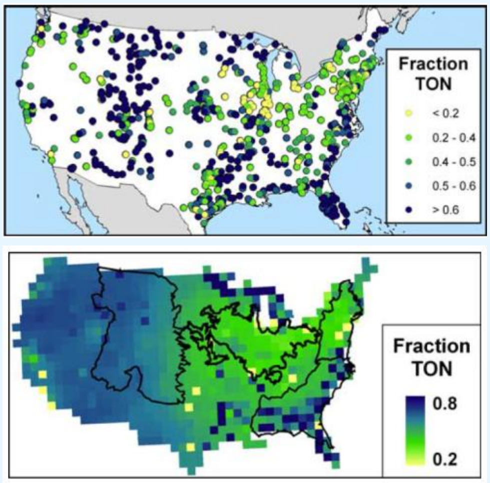
„Organic nitrogen appears to be the dominant form of nitrogen,…“

Organic nitrogen accounted on average for 48 % of total nitrogen export

Nitrate accounted on average for 41 % of total nitrogen export

Alvarez-Cobelas et al (2008) Environmental Pollution 156: 261-269

How much of the total N is organic N?



„…organic nitrogen ranged from less than 20% to over 80% of the total annual nitrogen yield (TON yields ranged from less than 15 to over 400 kg km^{-2} yr^{-1}).“

Scott et al (2007) Global Biogeochemical Cycles 21: GB1003

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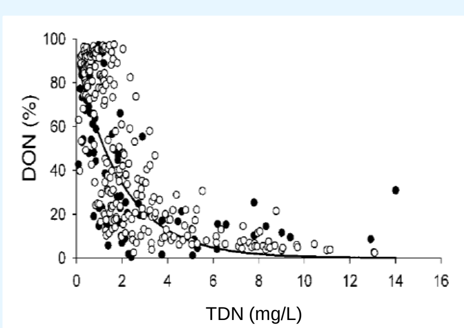
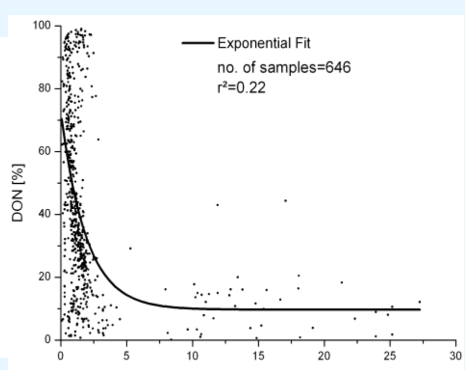
How much of the total N is organic N?



Wisconsin streams, Stanley & Maxted (2008) Ecological Applications, 18(7): 1579–1590, 324 samples



Germany; River Spree, 418 samples & Headwater streams, 235 samples, Data from IGB & PRESTO-Catch project

Conclusions: How much of the total N is organic N?

- **For low total nitrogen exports, organic nitrogen is often the dominant form**
- **For high nitrogen exports, nitrate is often the dominant form**
- **On a worldwide scale and in the USA, organic nitrogen seems to be the dominant form of nitrogen in the catchment export**

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Sources of organic nitrogen

Terrestrial

Aquatic

Sources of organic nitrogen in streams and rivers

Surface organic matter (Fresh plant material)

Soil organic matter

Groundwater

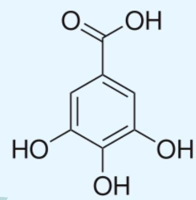
Terrestrial sources

In-stream production by aquatic macrophytes and algae

Aquatic sources

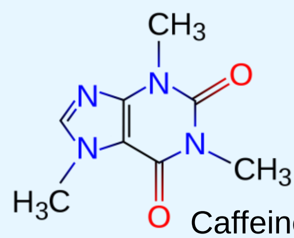
Fresh plant material

Leaching



Phenolic substances (gallic acid)

Tasty



Caffeine

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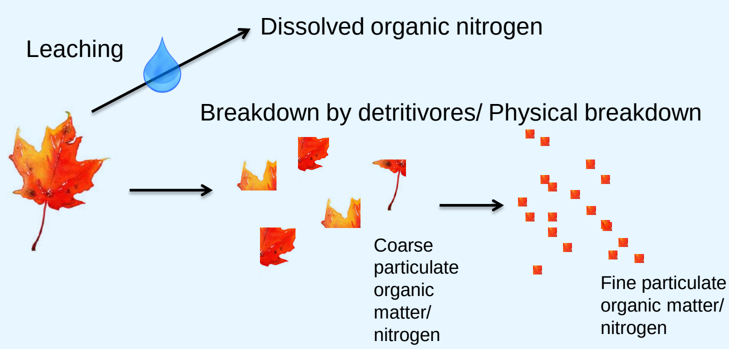
Fresh plant material

› **Source of particulate organic nitrogen (PON) and dissolved organic nitrogen (DON)**



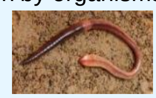
Formation of soil organic matter

- O - Loose organic matter
- A - Inorganic matter mixed with humus
- E – Eluviated horizon, contains little or no organic matter
- B – Zone of iluviation, containing materials transported from overlying horizons
- C – Weathered parent material, partly oxidized
- Slightly weathered and unaltered parent material

http://spot.pcc.edu/~kleonard/G202/Lecture4.html

Plant residues

Bioturbation by organisms



Uptake & release by microbial biomass

Eluviation (outwashing) and iluviation (enrichment)

Formation of soil aggregates, often associated with (and protected by) clay

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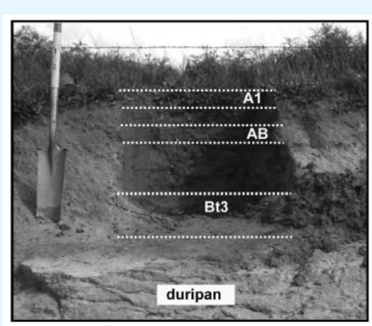
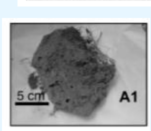
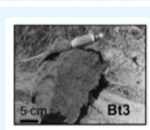
Large soil aggregates can keep soil organic matter (and org. N) very long

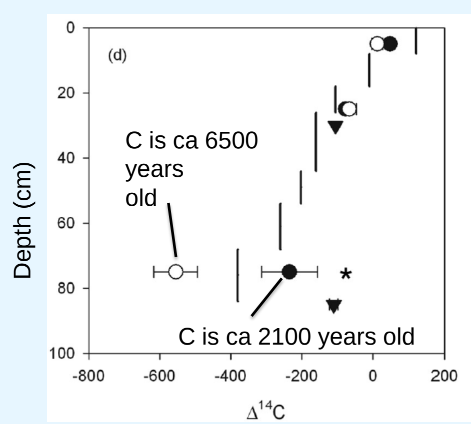






structural units:
1 to 10 mm in size

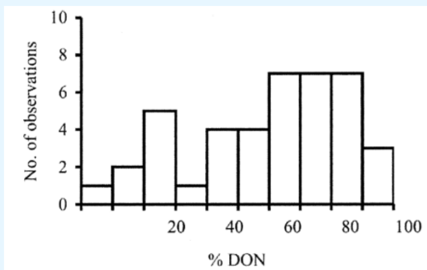
10 to 100 mm in size



Ewing et al. 2006 J Geophys Res 111: G03012

Groundwater

- **DON is a much more important fraction of organic nitrogen than PON**
- **In pristine groundwaters, most N is DON**
- **Groundwaters in Cape Cod, Massachusetts, USA;**



DON:
0.3 - 4.5 mg N / L

Low % of agricultural land use in the catchments

Kroeger et al (2006) Limnol. Oceanogr., 51(5):2248–2261

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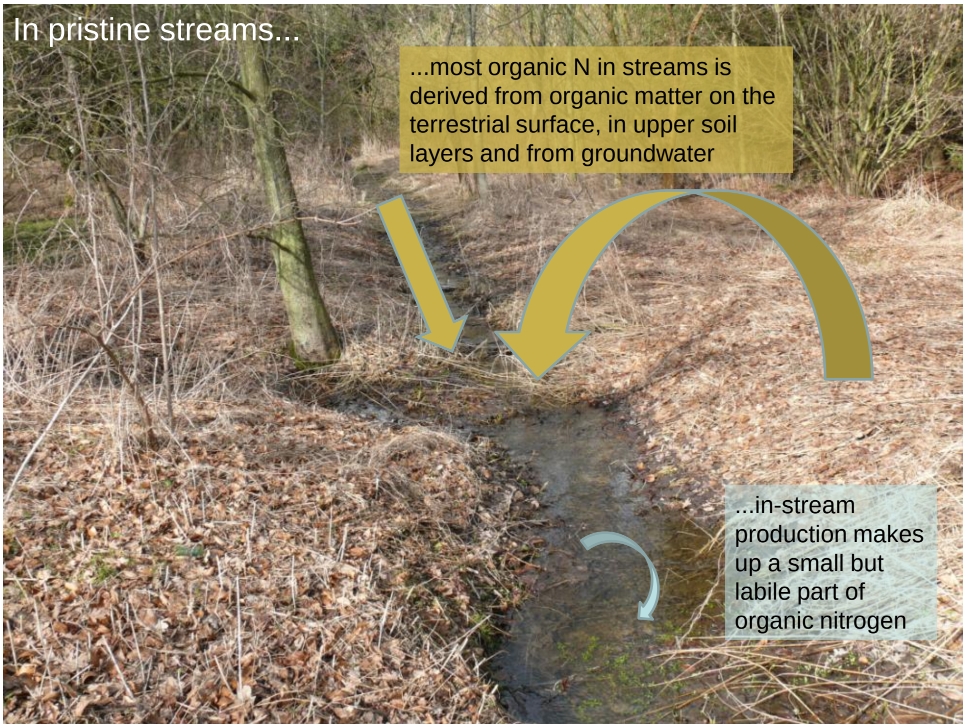
In-stream production by aquatic macrophytes and algae

- **Aquatic macrophytes can release DON and PON, similar to terrestrial plants**
- **Algae produce DON readily available to microbial organisms**
- **Phytoplankton itself is PON, suspended in the water column → Most algae in small streams are benthic algae**



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How does agriculture change organic nitrogen sources and concentration?

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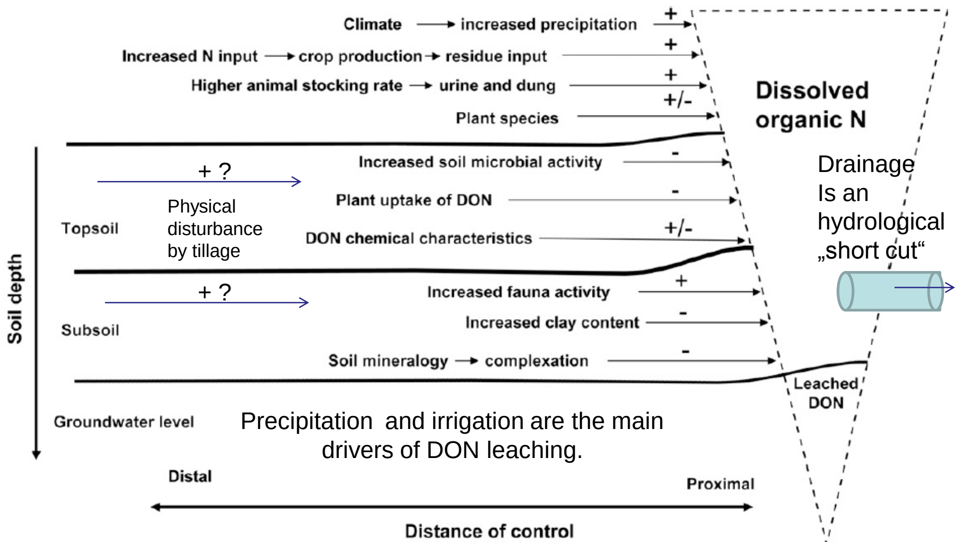
Driving forces of DON leaching in agricultural soils



Van Kessel et al (2009) J. Environ. Qual. 38:393–401

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What is changed, when a forest catchment is converted to arable land?

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What is changed, when a forest catchment is converted to arable land?

- **Clearcutting**

- **Tillage**

- **Inorganic & organic (manure) fertilizer application**

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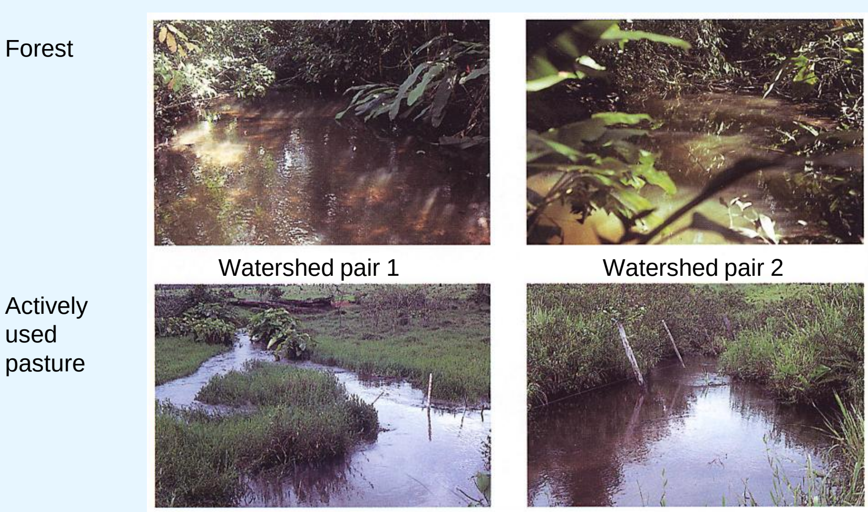
Clearcutting and pasture land use of Amazonian stream catchments



Neill et al (2001) Ecological Applications 11(6): 1817-1828

Clearcutting and pasture use of Amazonian stream catchments

Land use	Season	Dissolved oxygen (mg/L)	Mean daily temperature† (°C)
Watershed pair 1		Min-max	Mean (1 SE)
forest	dry	5.2–5.6	24.3 (0.09)
forest	wet	5.8–6.2	25.6 (0.04)
pasture	dry	0.1–0.2	24.6 (0.10)
pasture	wet	0.1–0.4	26.6 (0.06)
Watershed pair 2			
forest	dry	4.6–5.7	23.5 (0.11)
forest	wet	7.0–7.3	25.0 (0.04)
pasture	dry	0.2–1.4	24.4 (0.10)
pasture	wet	0.1–1.9	26.1 (0.05)

Only slight effect on temperature

Strong decrease in dissolved oxygen

Interpretation:
Low dissolved oxygen in pasture is probably the result of high organic matter inputs + low water flow and turbulence within streams

Neill et al (2001) Ecological Applications 11(6): 1817-1828

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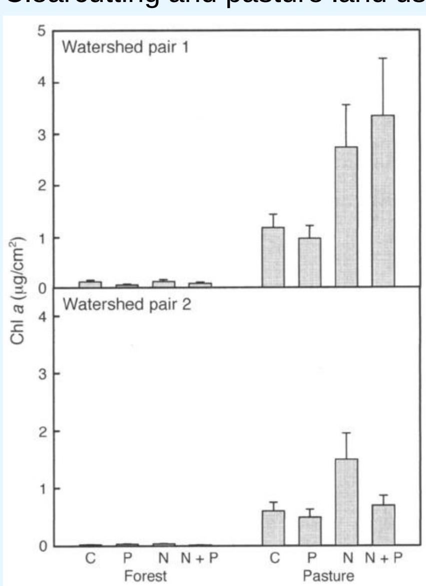
Clearcutting and pasture land use of Amazonian stream catchments



Results of disk periphyton bioassays in forest and pasture streams.

Nutrient addition treatments are:
C (control, no addition),
N (nitrogen),
P (phosphorus),
N + P (nitrogen plus phosphorus).

Chlorophyll a (Chl a) was measured as µg Chl a / cm^2 of ceramic disk surface

Higher light availability increases growth of benthic (stream bottom) algae

Neill et al (2001) Ecological Applications 11(6): 1817-1828

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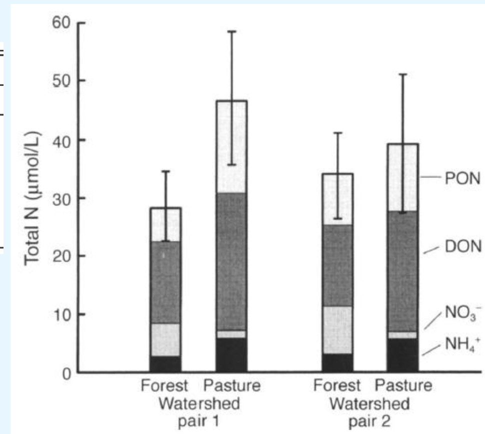
Clearcutting and pasture land use of Amazonian stream catchments

Soil lysimeter samples

Variable	Depth = 30 cm Forest	Pasture
NH_4^+ (µmol/L)	2.8 ± 1.6[a] (15)	4.6 ± 2.5[a] (15)
NO_3^- (µmol/L)	111.2 ± 21.7[a] (15)	3.3 ± 1.0[b] (15)
DON (µmol/L)	68.2 ± 13.1[a] (7)	33.4 ± 15.8[a] (6)

What may be the reasons for the differences in soil & stream water N concentrations?

Stream water samples



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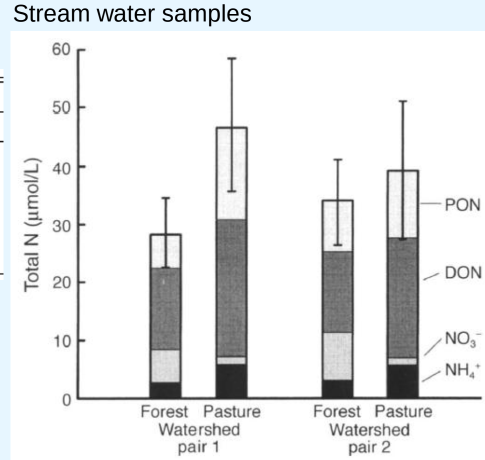
Low oxygen in soils → low nitrification →low NO3-→ low export to streams

NH4+ is not nitrified in soils→ transported to streams

Higher surface organic matter inputs + algal production → Higher PON and DON concentration

Stream water samples



Neill et al (2001) Ecological Applications 11(6): 1817-1828

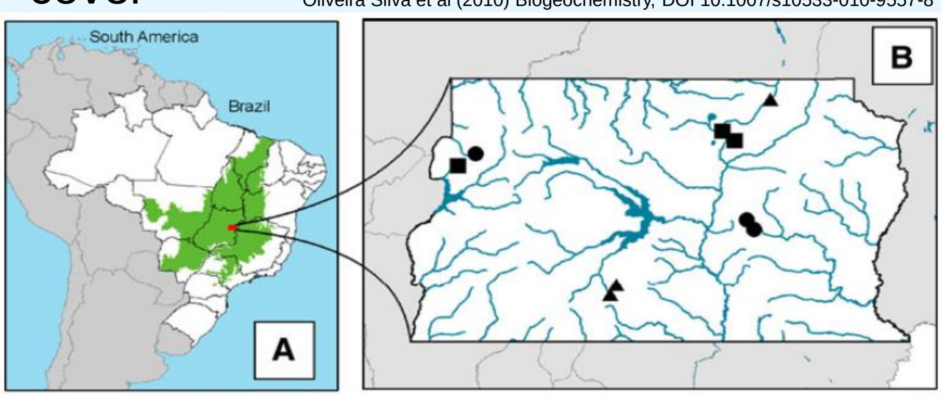
Conclusions:

Clearcutting and pasture land use of Amazonian stream catchments

- **Clearcutting increases light availability and benthic algae growth**
- **Pasture land use resulted in higher DON and PON concentrations probably by surface organic matter inputs and maybe also by algal production**
- **Pasture land use resulted in low nitrification and low nitrate concentrations in soils and streams**
- **Pasture land use resulted in low dissolved oxygen concentrations by high respiration due to organic matter inputs**

Cerrado streams under different land use cover

Oliveira Silva et al (2010) Biogeochemistry, DOI 10.1007/s10533-010-9557-8



Sampling from September 2004 to December 2006 every 2 weeks during the wet season (October to April), and monthly, during the dry season (May to September).

▲ natural cover ● rural cover ■ urban cover

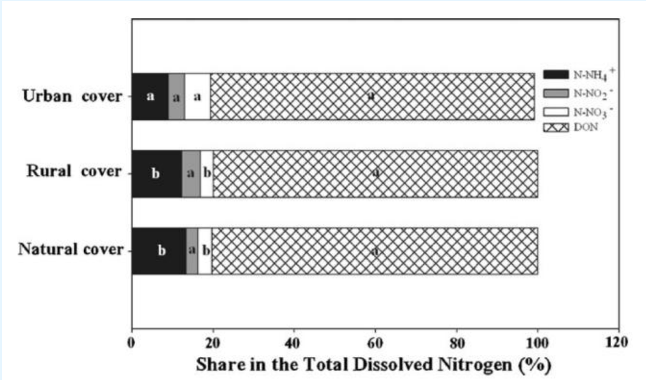
n = 3

↓

Pasture, soil bean and maize fields (> 50% of the catchment)

Concentrations are in µmol

Constituent	Natural cover		Rural cover		Urban cover	
	Wet	Dry	Wet	Dry	Wet	Dry
$N\text{-}NH_4^+$	4.11	3.03	5.75*	3.76	7.65	6.06
$N\text{-}NO_2^-$	2.16*	0.86	3.11*	0.96	3.76	3.39
$N\text{-}NO_3^-$	0.67	0.49	0.98	0.73	3.06	3.11
TDN	20.29	17.85	21.68*	15.89	35.62	34.20
DOC	125.14*	95.51	121.74*	91.00	146.70*	117.05



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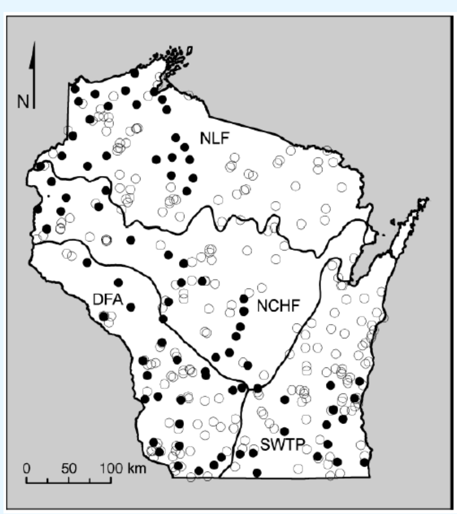
Streams in Wisconsin under different land use cover

Sample sites of the study:



Three types of streams:

a. Forested: >50% of forest
b. Mixed: no dominant land use type
c. Human: with > 50% agriculture and urban

Stanley & Maxted (2008) Ecological Applications, 18(7): 1579–1590

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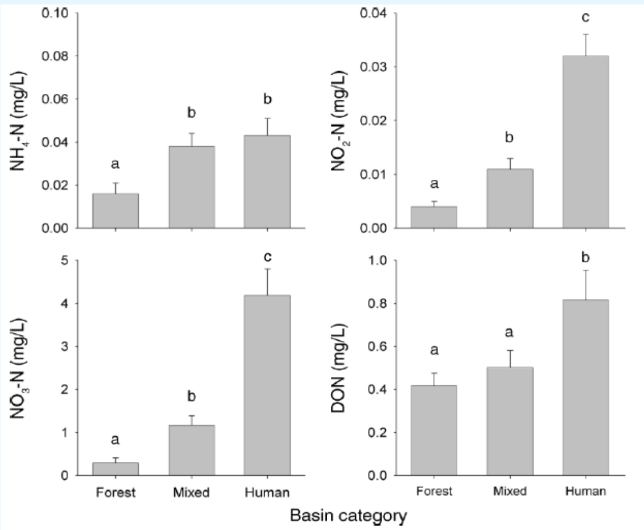
Streams in Wisconsin under different land use cover



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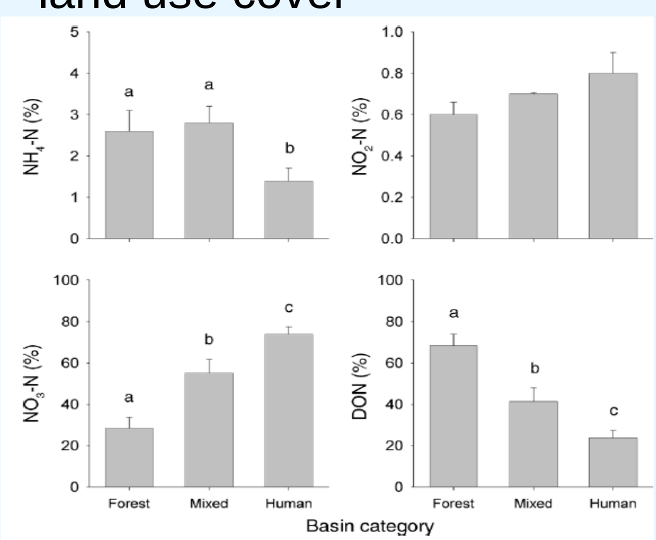
Streams in Wisconsin under different land use cover



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Stanley & Maxted (2008) Ecological Applications, 18(7): 1579–1590

Temperate-tropical comparison from the three examples

- **DON concentration increases with agricultural and urban land use (Amazonian region, Wisconsin)**
- **In tropical streams the DON to total N ratio does not change**
- **In temperate streams the DON to total N ratio decreases with increasing agricultural and urban land use change**

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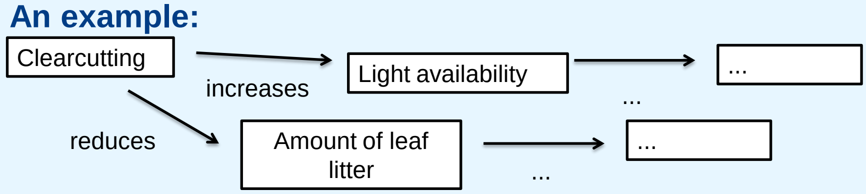
Draw a concept map, creating some hypotheses on the following question:

- **How does agriculture affect the sources and amount of organic nitrogen in streams?**
- **An example:**



- **Assume an agricultural stream, affected by <u>clearcutting</u>, <u>tillage</u> & <u>organic (manure)/ inorganic fertilizer application</u>**
- **10-15 min, with a little presentation afterwards**

How does agriculture affect the sources and amount of organic nitrogen in streams?

- **Clearcutting**

- **Tillage**

Clearcut ting —increases→ Light availability → ... → ...

Clearcut ting —reduces→ Amount of leaf litter → ... → ...

- **Inorganic & organic (manure) fertilizer application**

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Organic nitrogen processing in streams

- **PON and DON have to be investigated separatedly**
- **PON is prone to sedimentation, while DON is not**
- **Organic nitrogen is only used in assimilative uptake (= for biomass production), not in dissimilative uptake (= for energy production)**
- **DON processing depends on its composition**
  - **It has a refractory (not available for uptake) and a bioavailable (available for uptake) part**

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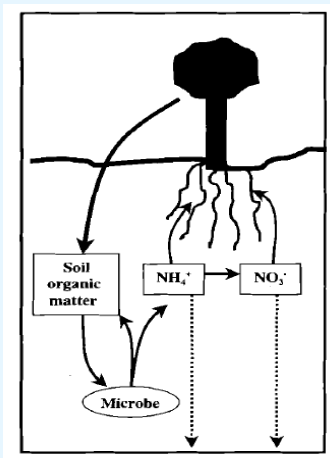
Uptake of DON: classical view

› **Classical terrestrial N cycle**



Neff et al Front. Ecol. Environ. (2003) 1(4):205:211

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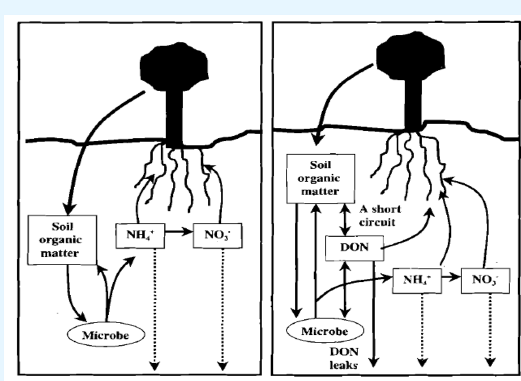
Uptake of DON: actualized view

› **Uptake of DON by macrophytes and algae**

› **An hypothesis from terrestrial ecologists:**



„Short-cutted“ terrestrial N cycle

Marine phytoplankton also was found to take up DON, See review Berman & Bronk (2003) Aquat Microb Ecol 31: 279–305

Neff et al Front. Ecol. Environ. (2003) 1(4):205:211

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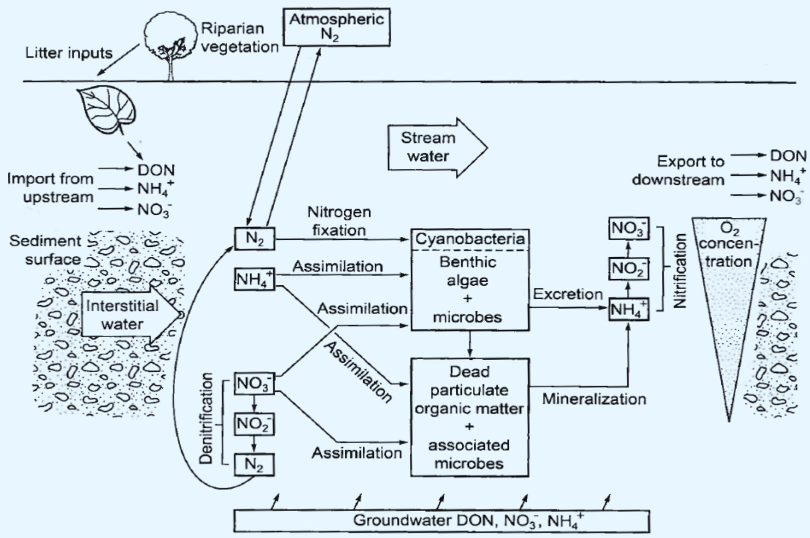
N dynamics in a stream (classical view)



Allan & Castillo 2007. Stream Ecology. 2nd edition

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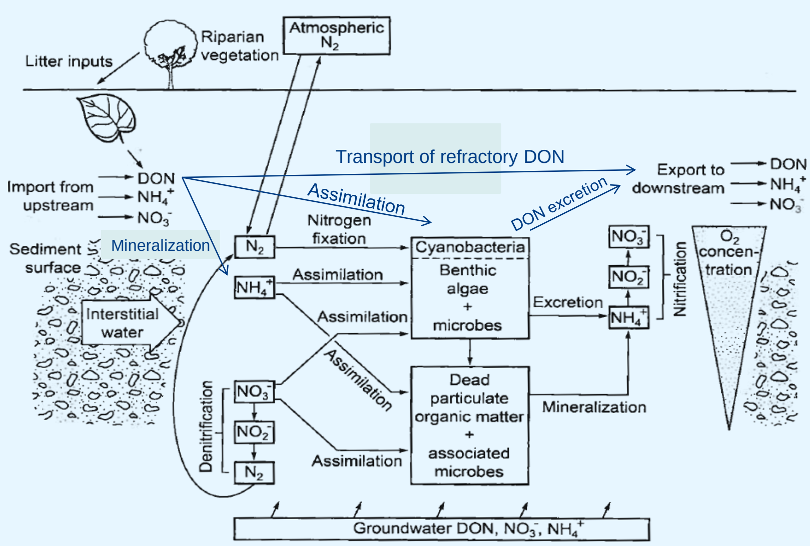
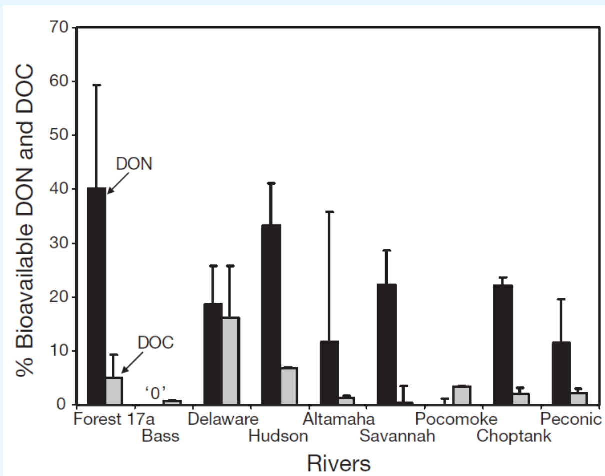
N dynamics in a stream (actualized view)



Allan & Castillo 2007. Stream Ecology. 2nd edition

Bioavailability of DON in 9 US rivers



Bioavailability after 6 days of incubation

Same inoculum was used

High variability of DON bioavailability

Different DON composition?

Wiegner et al (2006) Aquatic Microbial Ecology 43: 277–287

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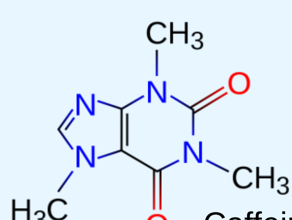
Daniel Graeber – Organic nitrogen
Nutrient Cycling, Modeling and Management from Field to Catchment Scale

The end

› **Lets take up some organic nitrogen (Mate)**



Caffeine