

Source-separation for circularity of nutrients and reuse in agriculture

Julien Le Roux, Régis Moilleron, Fabien Esculier, Tanguy Fardet, Thomas Starck

leesu

UPEC
Connaissance - Action

UNIVERSITÉ
PARIS-EST CRÉTEIL
VAL DE MARNE

ÉCOLE NATIONALE DES
PONTS
ET CHAUSSEES

SmartWater Twin
Waste Water Management
in Circular Economy

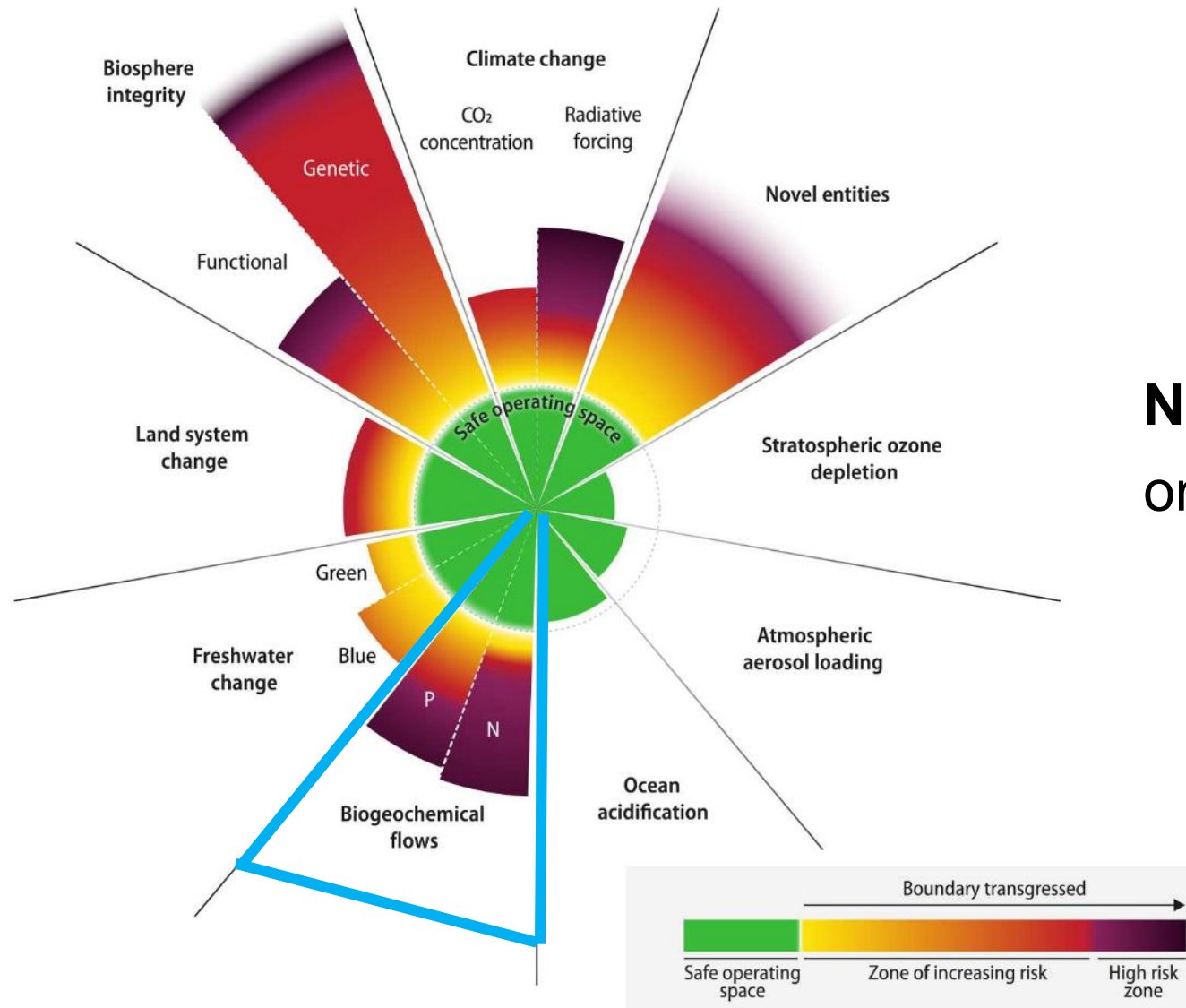


Funded by
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SmartWater Summer FORUM

18-20. September 2024. Novi Sad

Planetary boundaries



Nitrogen and phosphorus cycles:
one of the six transgressed boundaries

The nitrogen path to our plates



→
 N_2

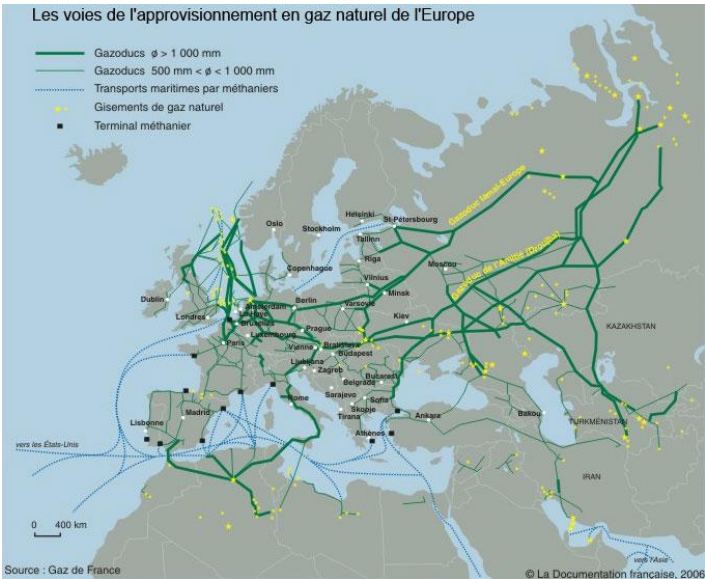
Haber-Bosch process



2.5% of
greenhouse
gases
emissions in
France



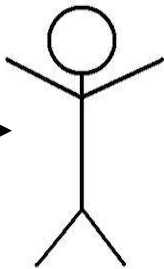
Methane
(natural gas)



Chemical
fertilizers ↓



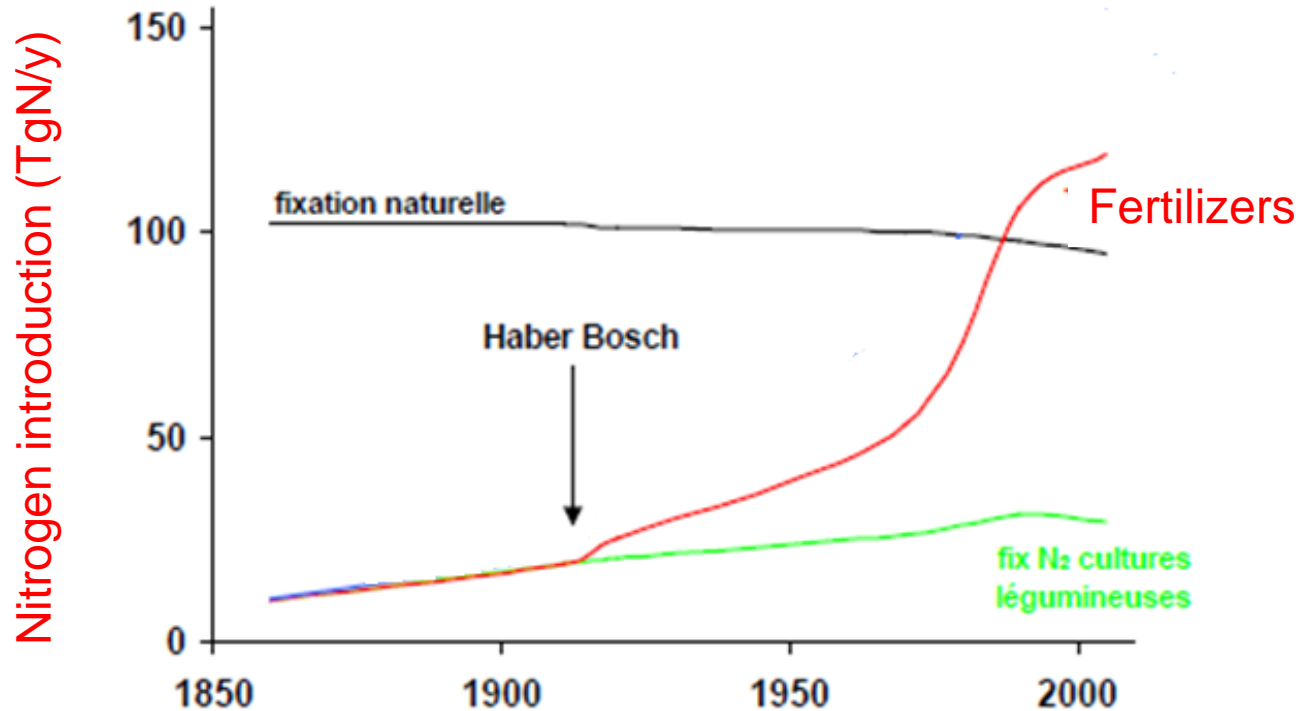
20-50 kg N



5 kg N

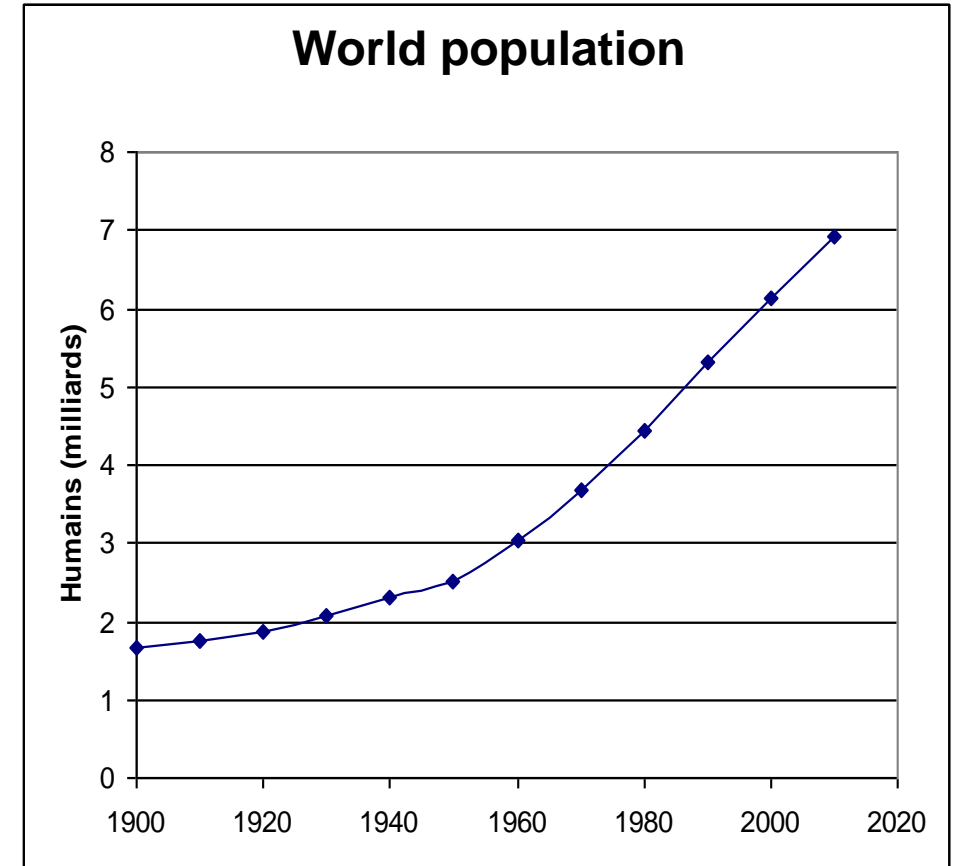
3

More than a revolution



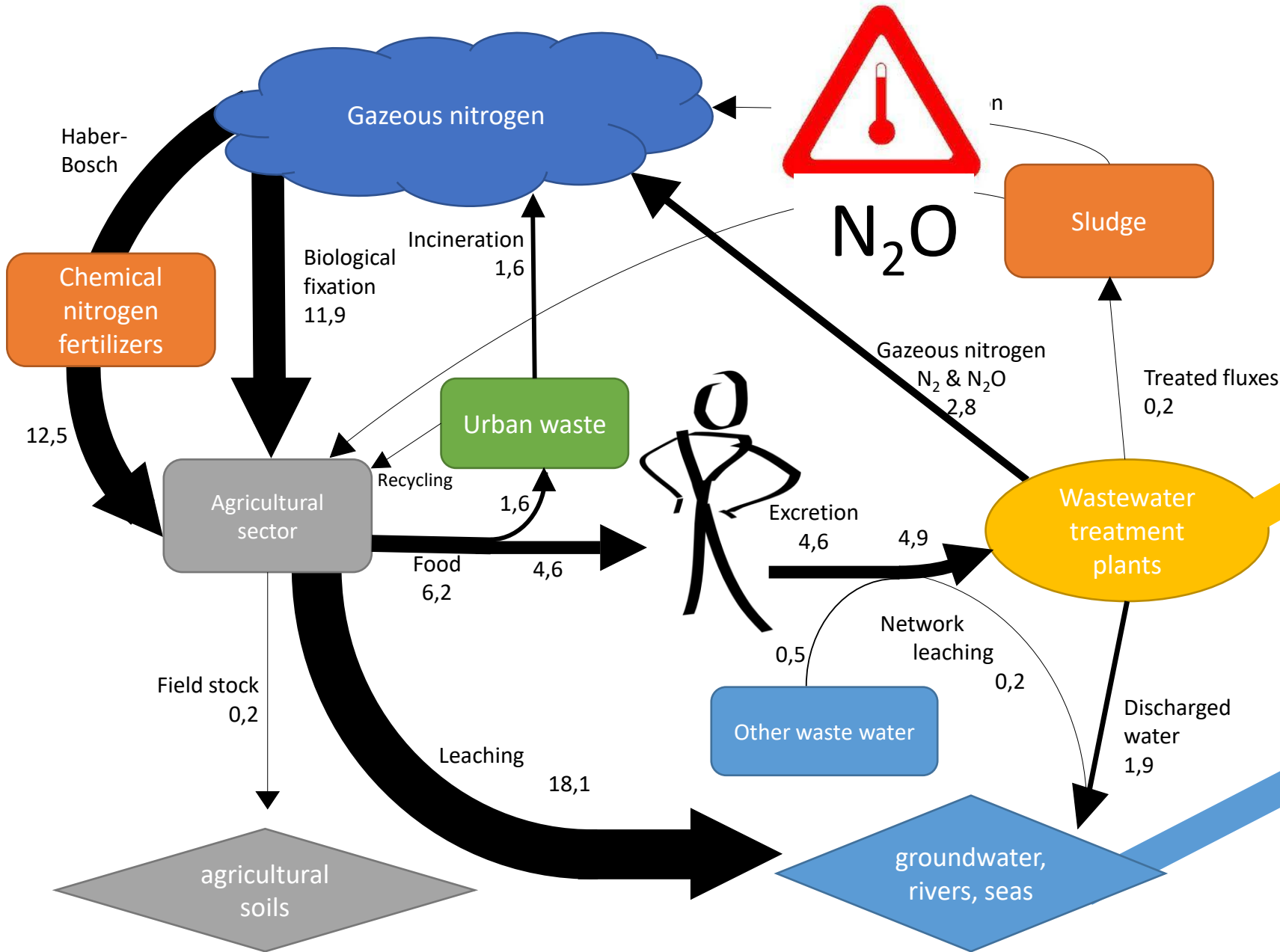
« Anthropocene »

(Paul Crutzen, 2002)

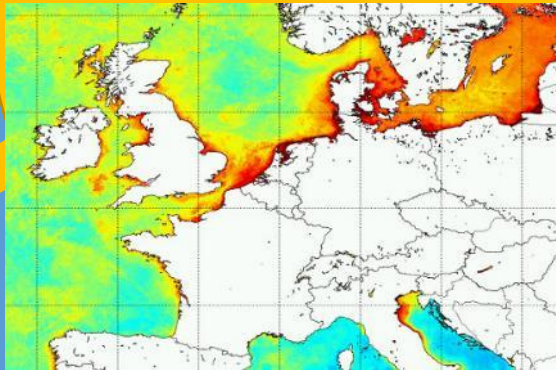


US Census Bureau ; ONU,
2012

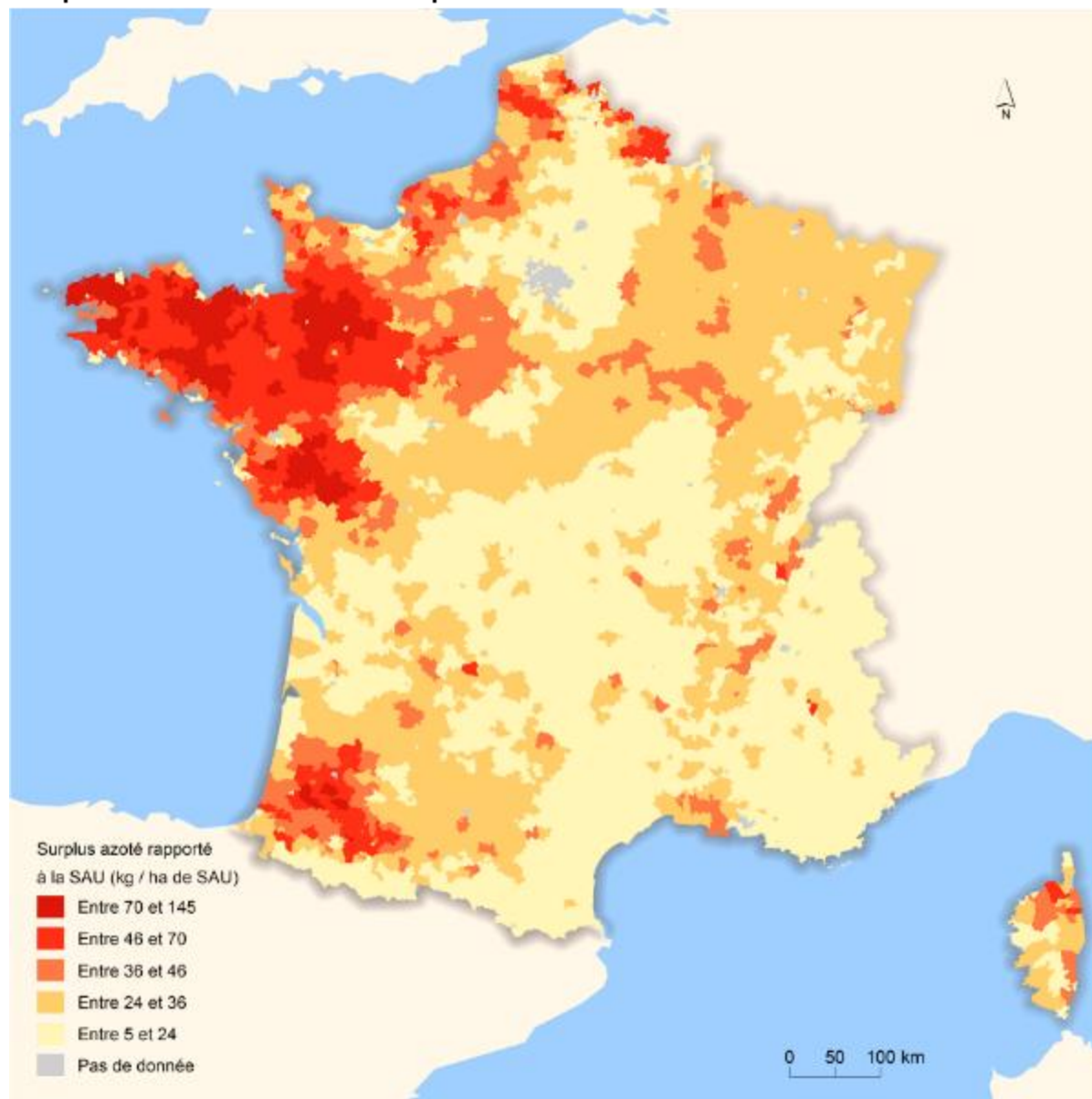
A crazy nitrogen cycle ? (kgN/year/inhab)



eutrophication



Répartition territoriale du surplus azoté en 2010 à l'échelle du canton



Champ : France métropolitaine.

Source : SOeS. Nobolu - aari 2010. Traitements : SOeS. 2014



AFP/Damien Meyer



Regulation



Urban Wastewater Treatment Directive

European Framework Directive 21 may 1991 (91/271/CEE)

French Water Law 1992 - Decrees n°94-469 & 2000-318

→ **France : Decree 21 july 2015** for collection, transportation and treatment of wastewater in urban areas, and for individual *on-site* sanitation systems

(+ modifications in decree 31 july 2020)

- **Minimum levels of treatment**
- **deadlines for conformity of WWTPs**
(depends on city size, and sensitive areas)

→ **sensitive areas**

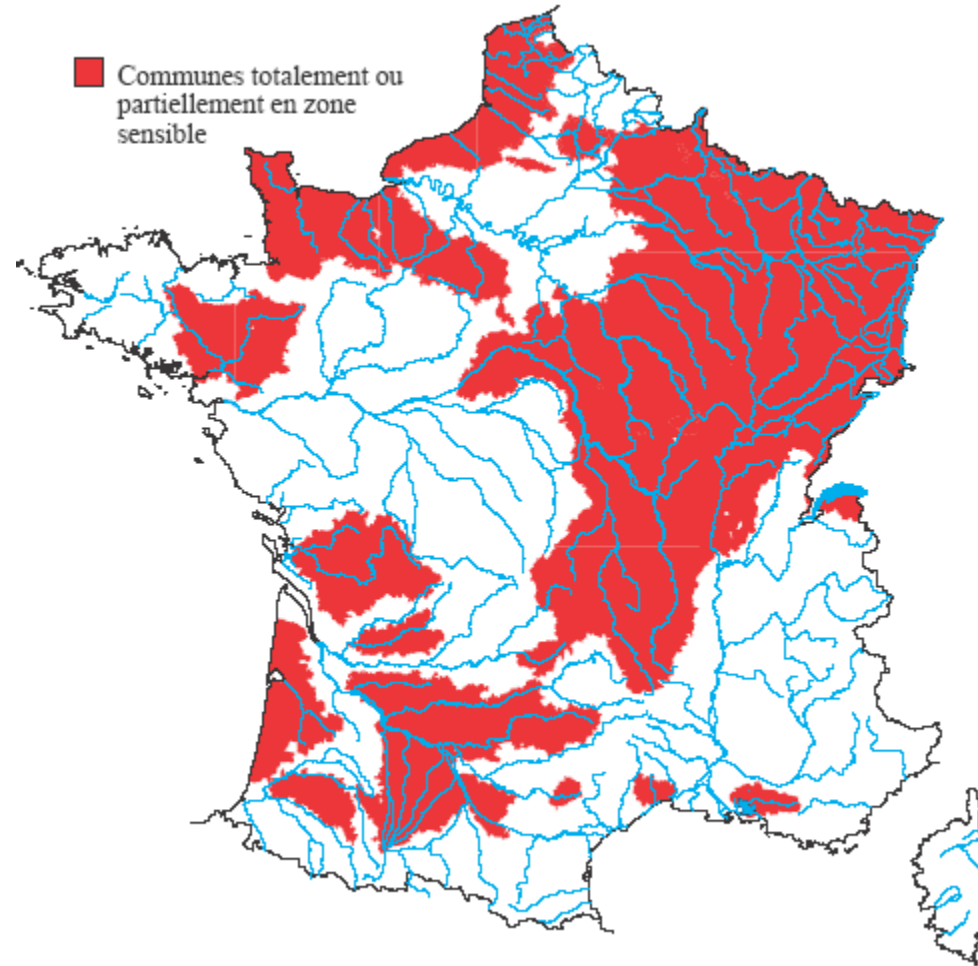
Sensitive to eutrophication: N & P discharges to be reduced

Specific protections of: water intakes, swimming areas, fish farming...

Sensitive areas

- 1998: 45% of surface
- 2006: 69%

2006



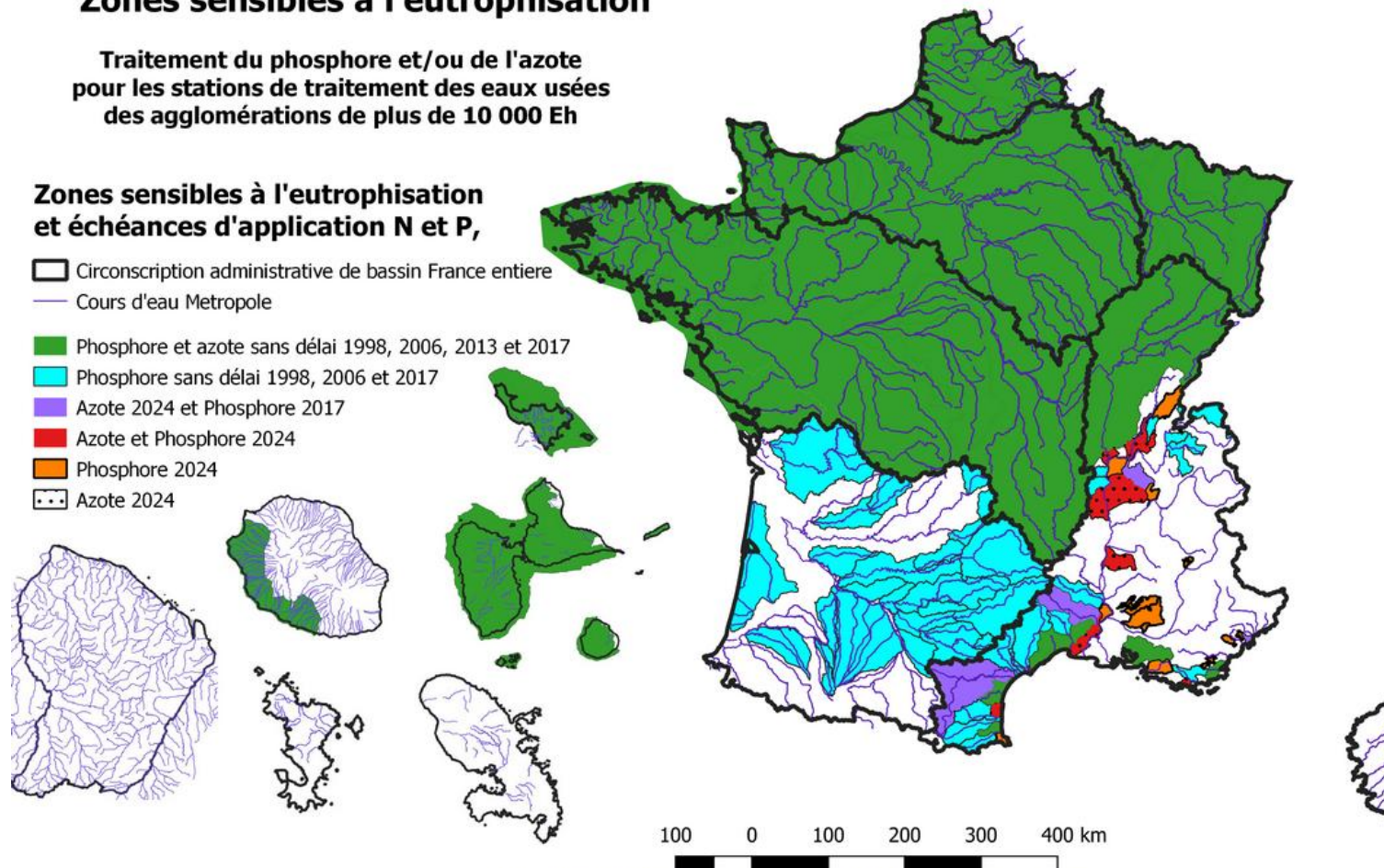
Sensitive areas

Directive ERU 91/271/CEE Zones sensibles à l'eutrophisation

Traitement du phosphore et/ou de l'azote
pour les stations de traitement des eaux usées
des agglomérations de plus de 10 000 Eh

Zones sensibles à l'eutrophisation et échéances d'application N et P,

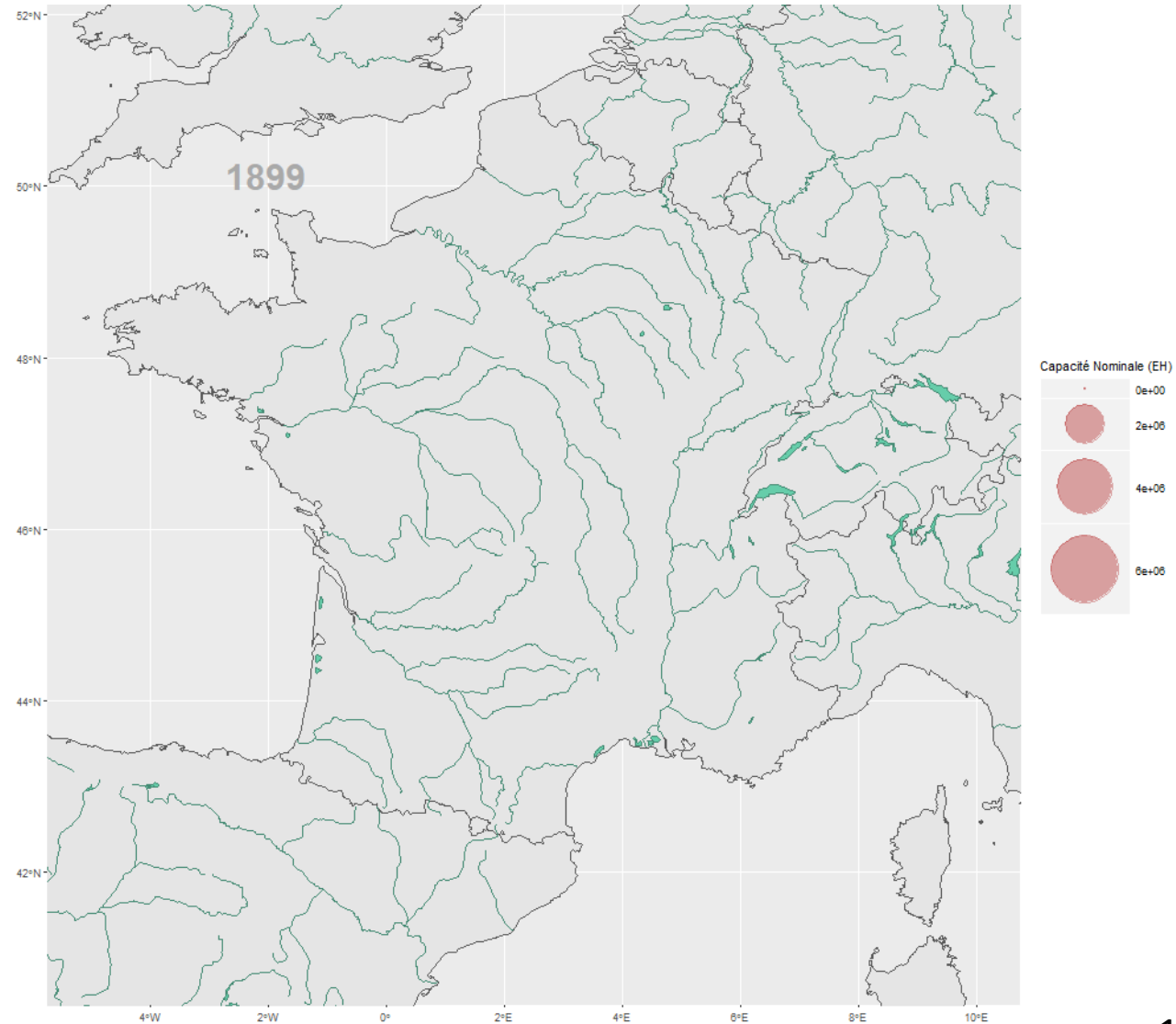
-  Circonscription administrative de bassin France entière
-  Cours d'eau Metropole
-  Phosphore et azote sans délai 1998, 2006, 2013 et 2017
-  Phosphore sans délai 1998, 2006 et 2017
-  Azote 2024 et Phosphore 2017
-  Azote et Phosphore 2024
-  Phosphore 2024
-  Azote 2024



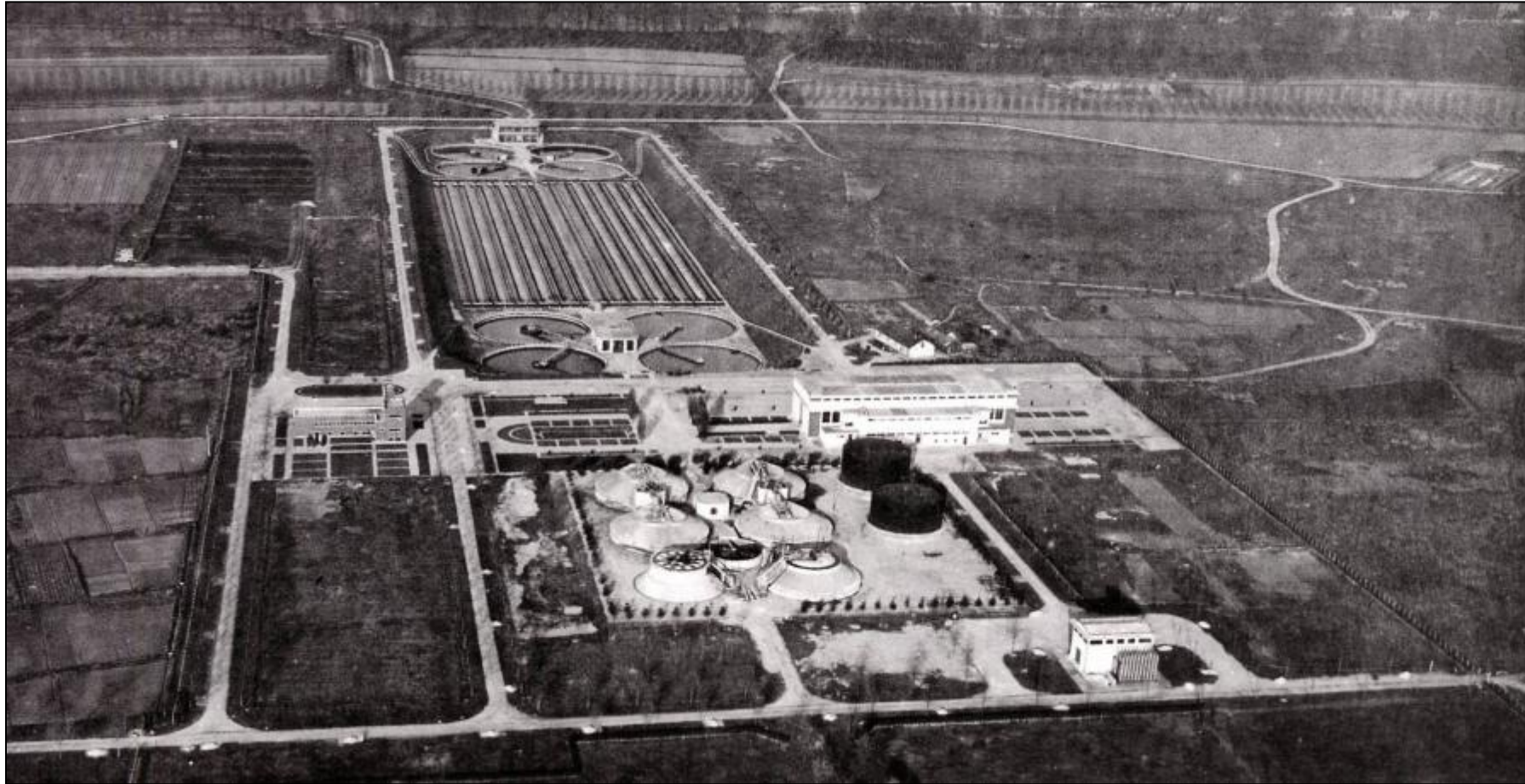
La liste des zones sensibles est disponible à l'adresse: <http://assainissement.developpement-durable.gouv.fr/services.php>

2020

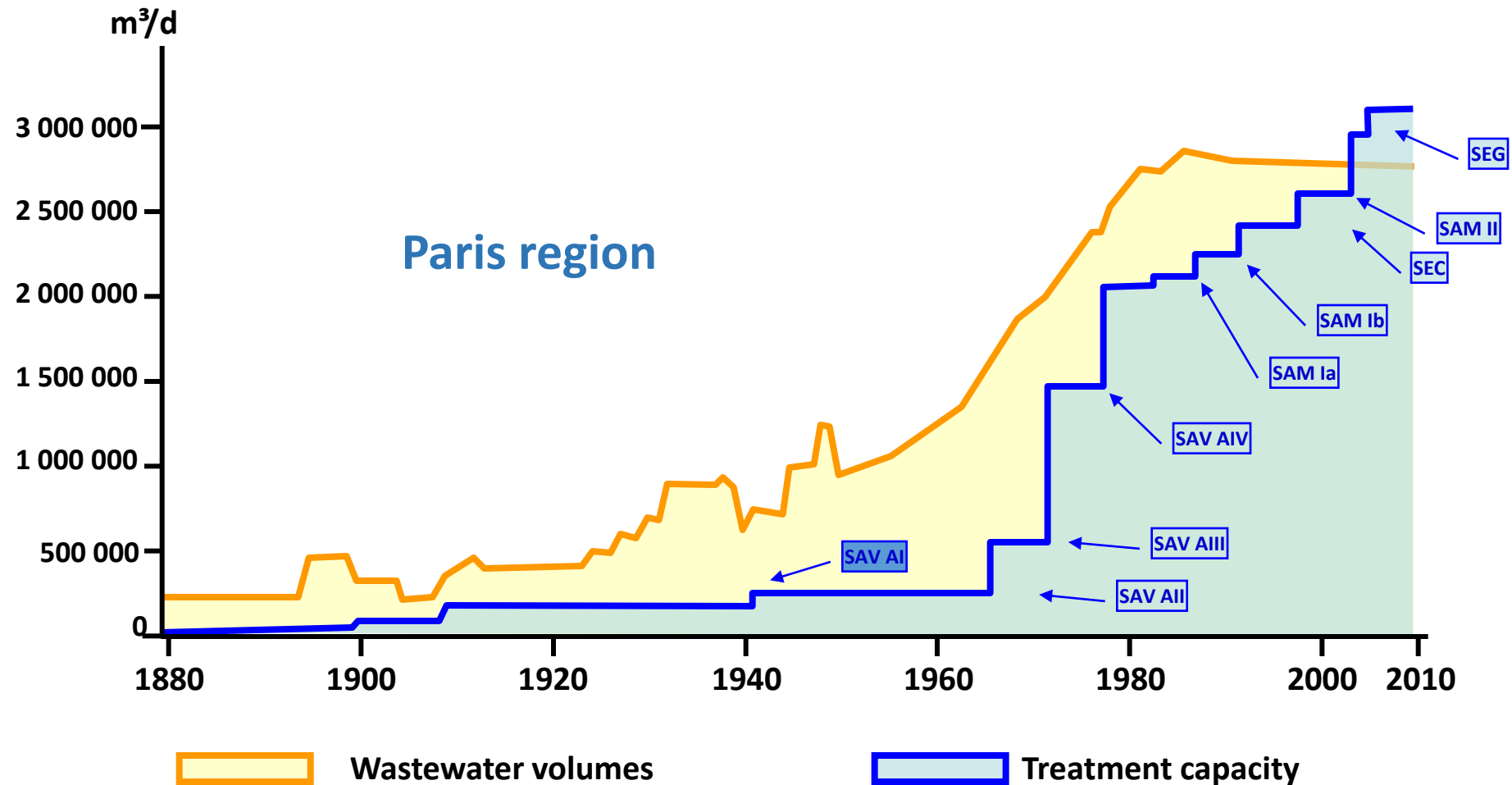
WWTPs built in France over the years



1940: Achères 1



WWTPs trying to catch up



Regulation

Conformity of WWTPs in France

Situation in 12/2019 for 3 989 WWTPs (> 2 000 inh.)

3234 (81%) with good performances

718 (18%) not complying with treatment efficiency
(for C and/or P & N)

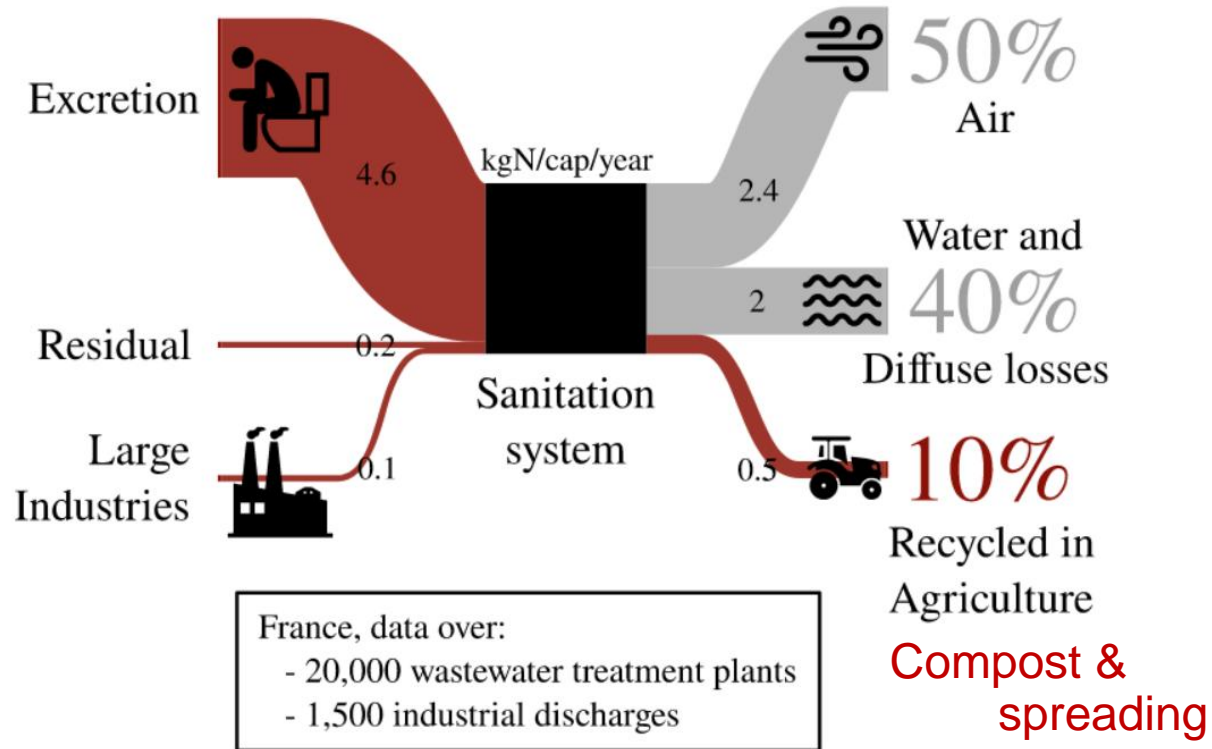
Each year: 2 à 3% of WWTPs need to be replaced/renovated because of insufficient capacity (or old equipment).

50 to 100 WWTPs each year! (for cities > 2000 inh.)



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Nitrogen as a resource?



Science of The Total Environment

Volume 912, 20 February 2024, 168978



Fate of nitrogen in French human excreta: Current waste and agronomic opportunities for the future

Thomas Starck ^a, Tanguy Fardet ^a, Fabien Esculier ^{a, b}

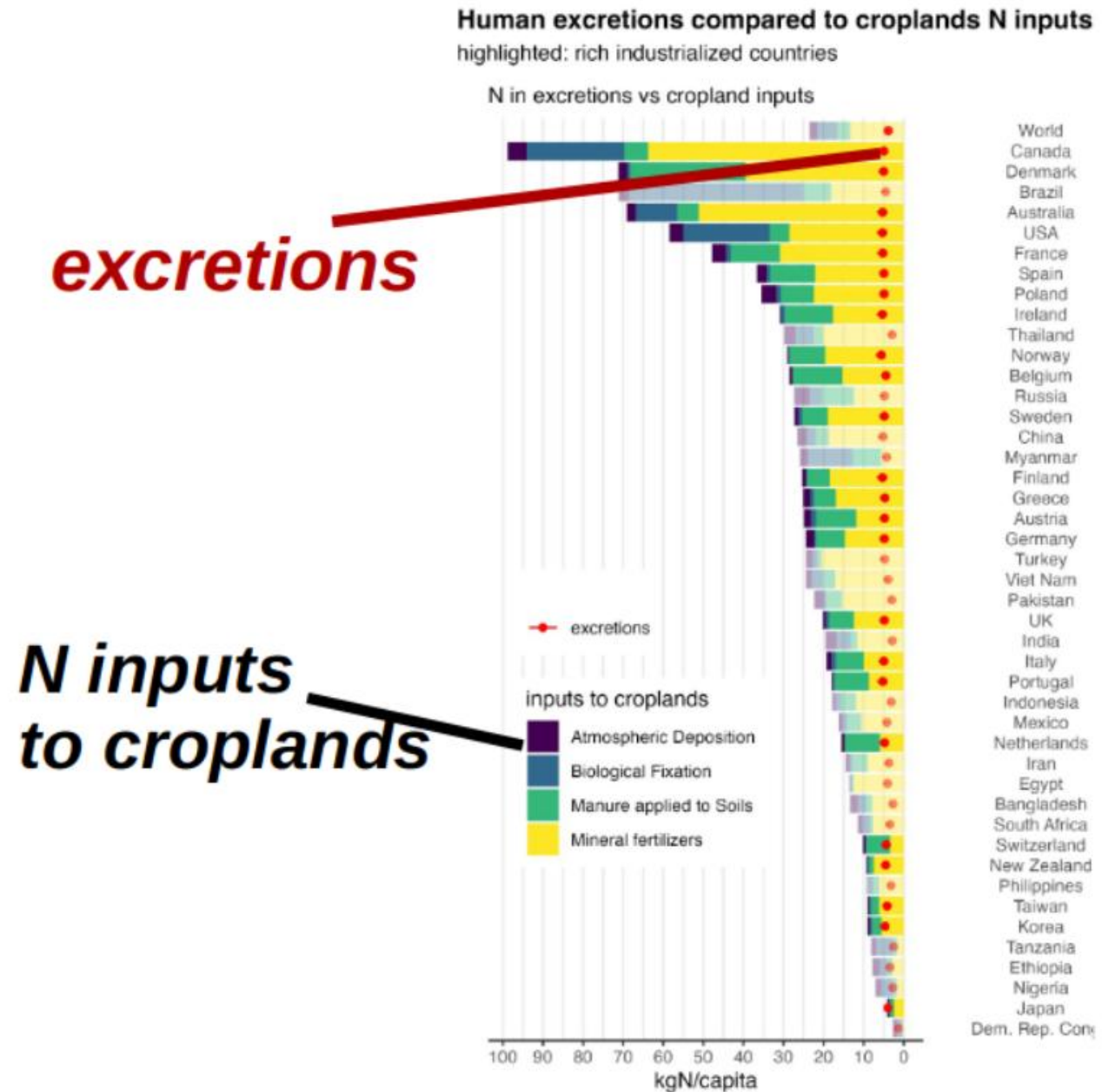
<https://doi.org/10.1016/j.scitotenv.2023.168978>

Thomas Starck PhD thesis

What is the potential of human N excretions for fertilization?

Spatial constraint: How to match excretions and uses in crops?

FAOSTAT data on cropland N inputs vs human N excretion (3-5 kgN/cap)





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How much fertilizer can be replaced by urine?

15% in France
25% worldwide

<https://thomas-starck.github.io/potential-human-excretions-fertilization/potential.html>

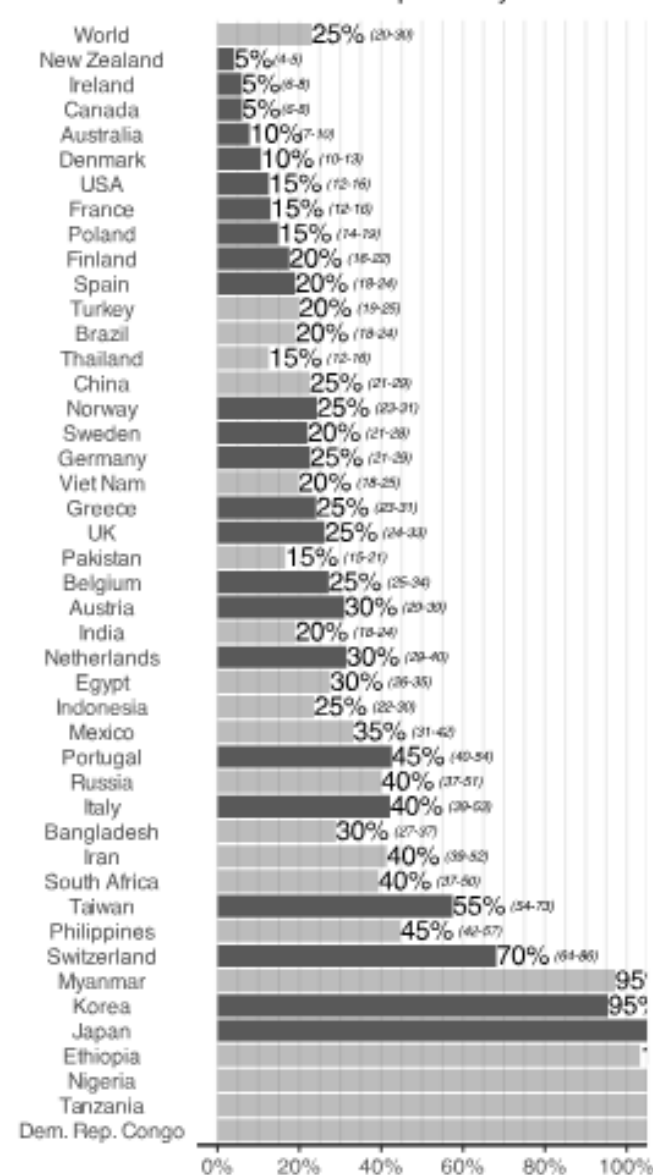
Maximum potential substitution of synthetic fertilizers by human urine

highlighted: rich industrialized countries

N in urine and fertilizers consumption



% of fertilizers replaced by urine



based on FAOSTAT data for 2015-2020



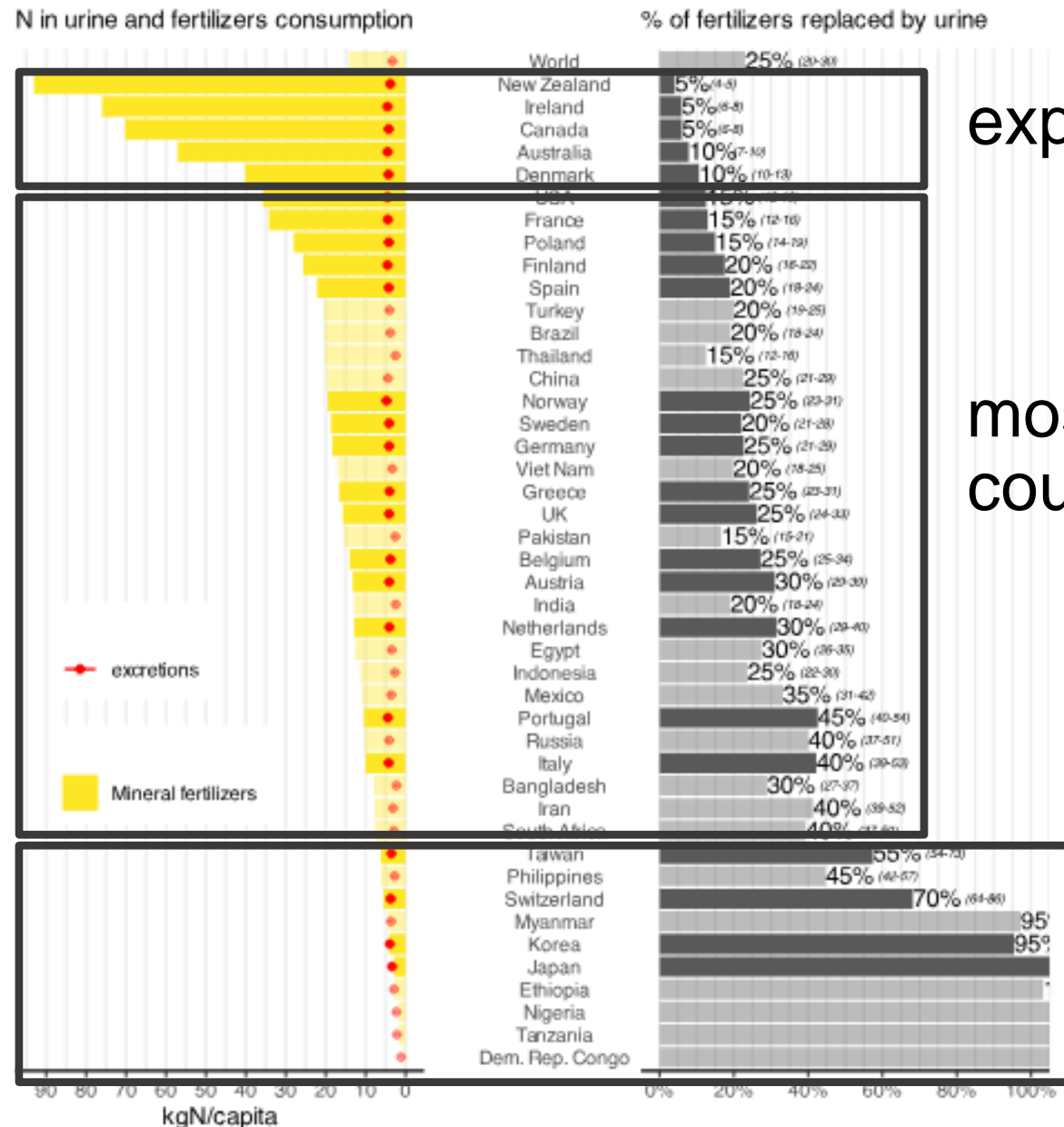
How much fertilizer can be replaced by urine?

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Maximum potential substitution of synthetic fertilizers by human urine

highlighted: rich industrialized countries



exporters

most countries

sub-saharan Africa & rich industrialized Asia

Most N used for animal production in rich industrialized countries

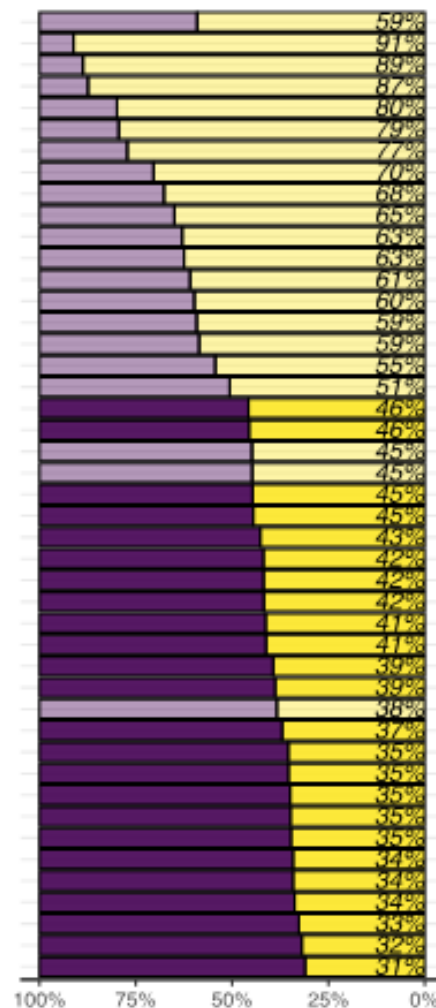
<https://thomas-starck.github.io/potential-human-excretions-fertilization/potential.html>

Repartition of vegetal and animal products in N food supply

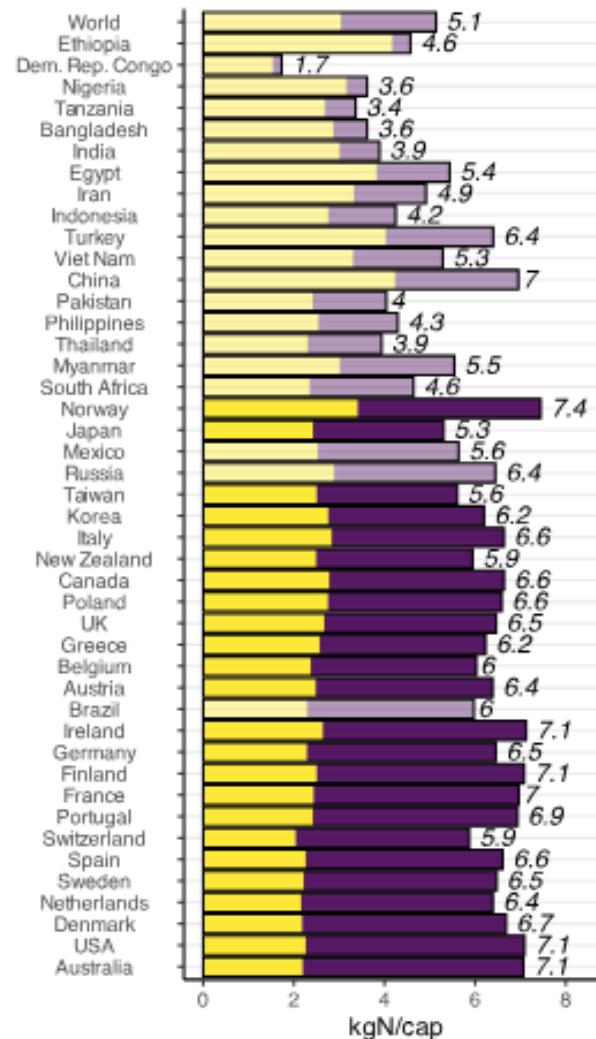
highlighted: rich industrialized countries

relative shares

■ animal ■ vegetal

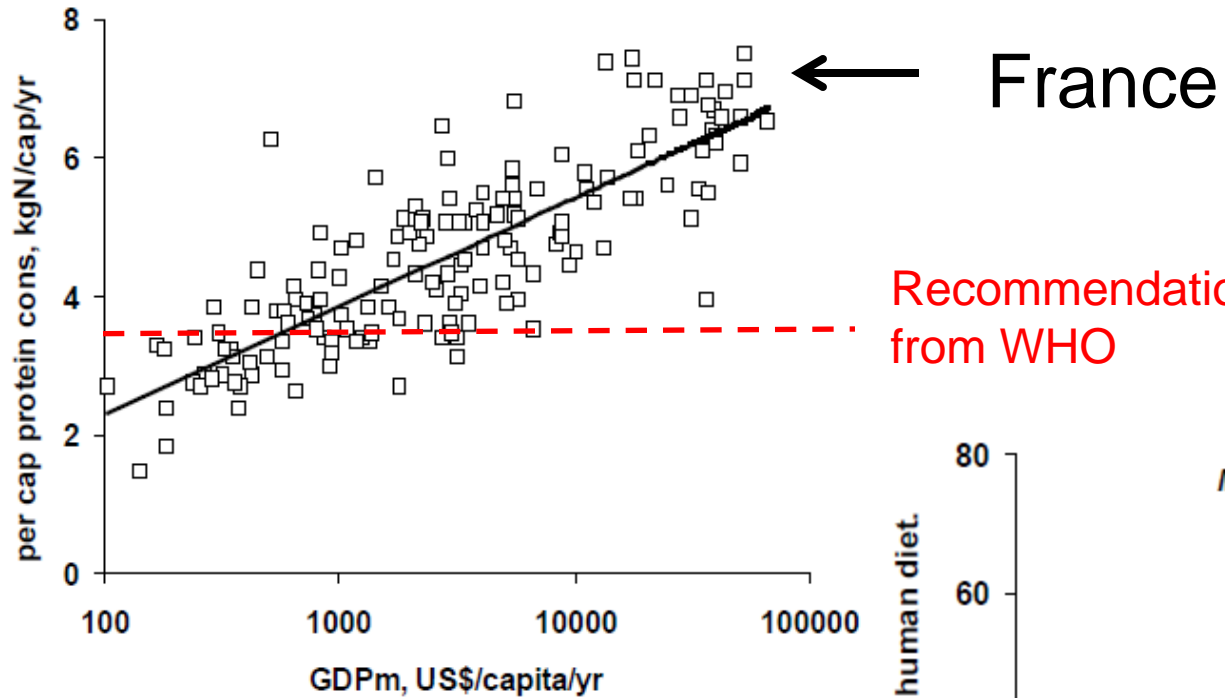


absolute quantities

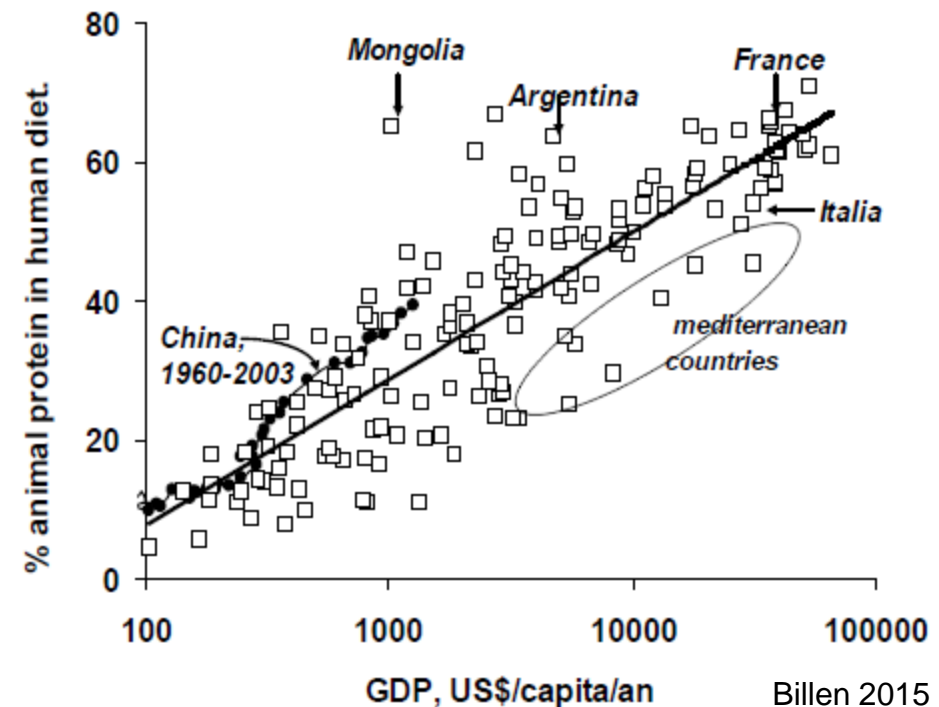


20 based on FAOSTAT data for 2015-2020

Protein consumption



1. Limit the consumed amounts
2. Favor vegetal proteins



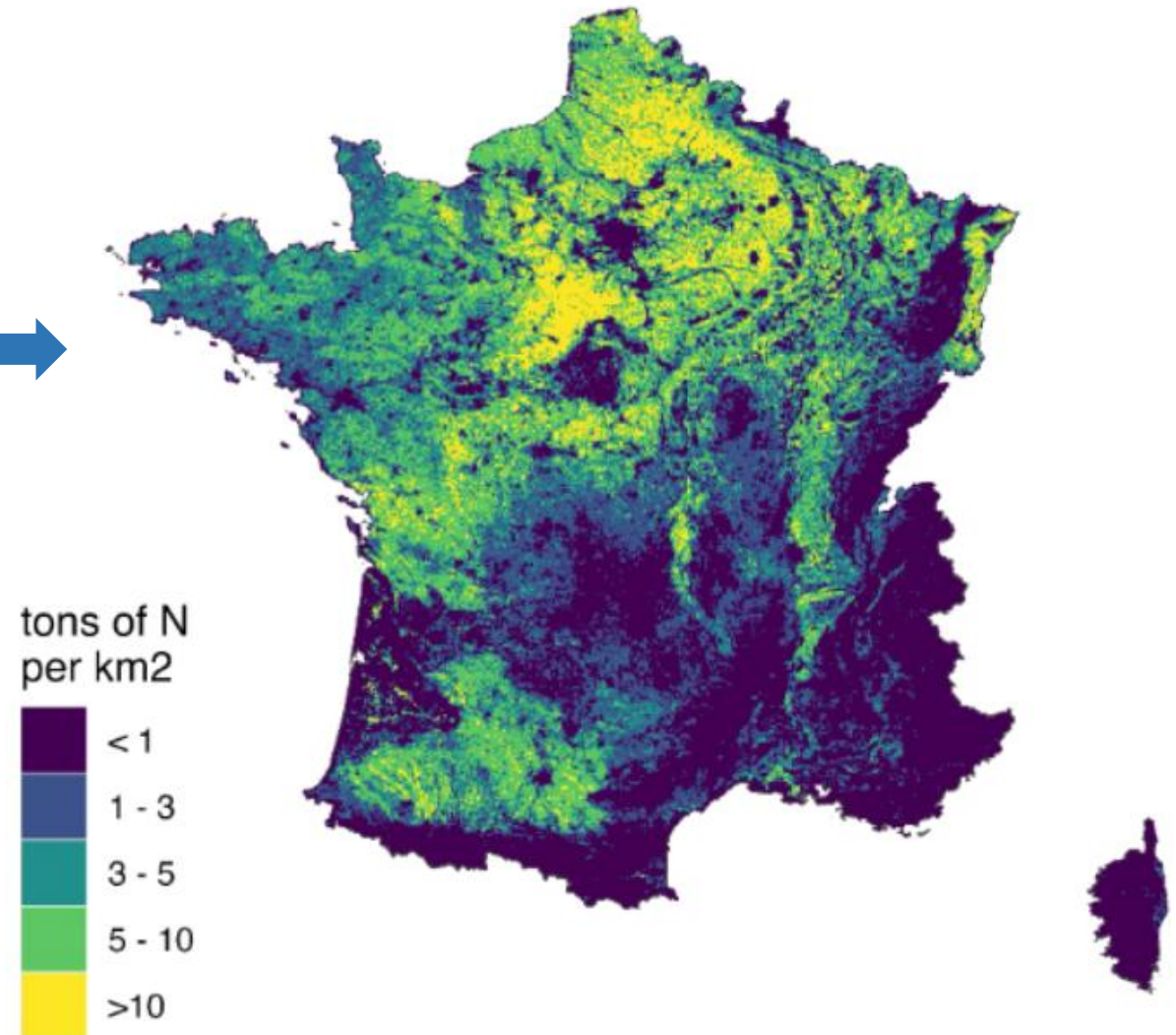
Where can we use source-separated urine?

Substitute this
by human N excretions?
(~300 ktN/y)



Mineral fertilization

(~2000 ktN)



Where can we use source-separated urine?

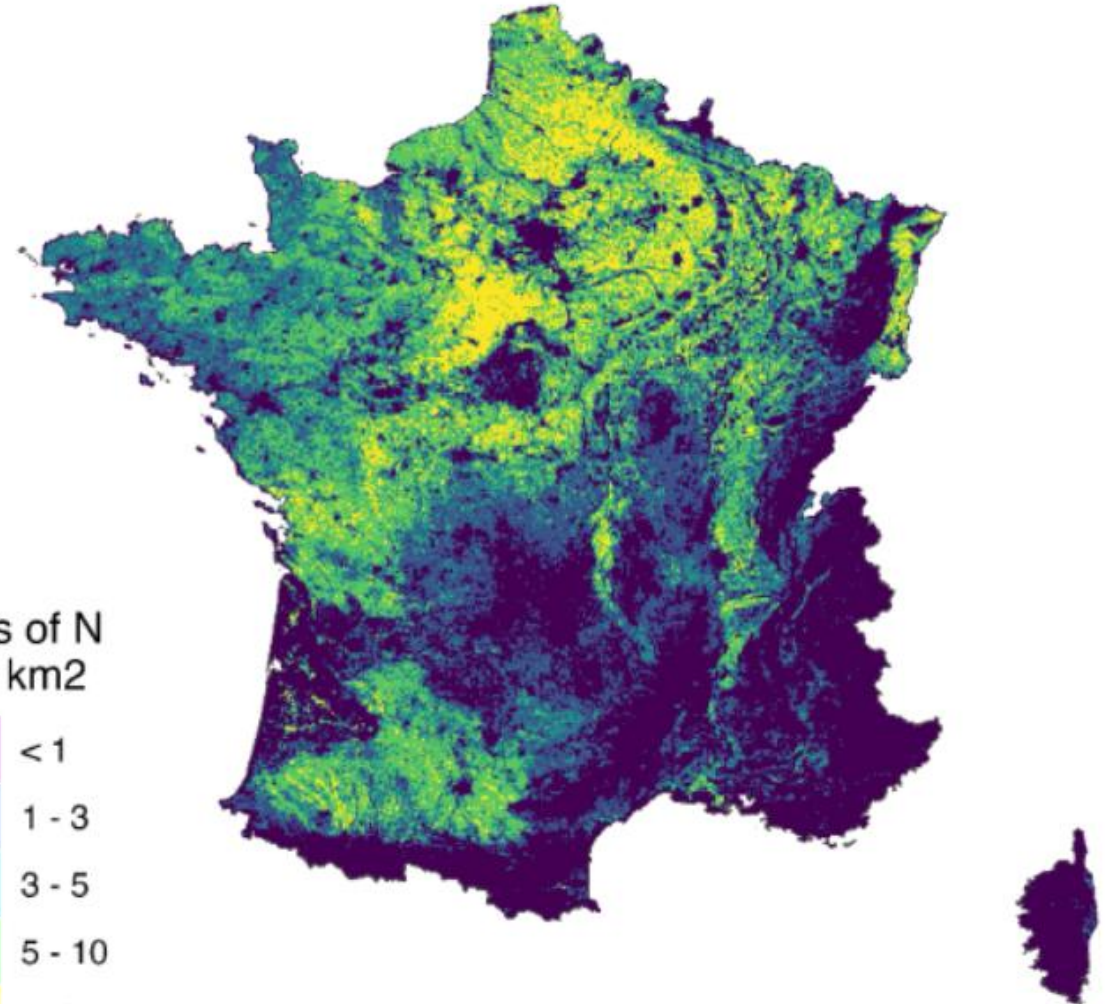
Mineral fertilization

(~2000 ktN)

N excretions



tons of N
per km²



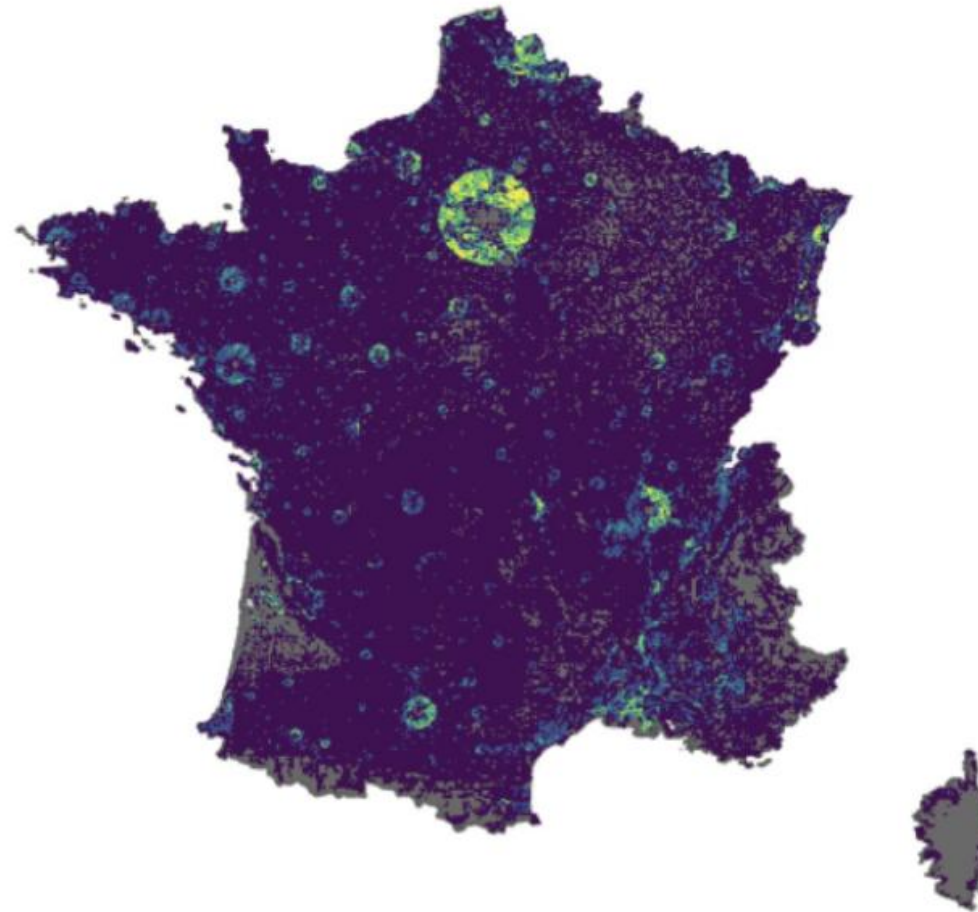
population data + N ingestion

Where can we use source-separated urine?

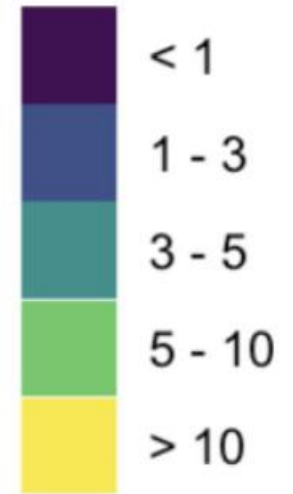
fertilization with excretions

Algorithm to substitute mineral N by human excretions on neighbouring parcels

Most excretions could be spread at < 10 km!



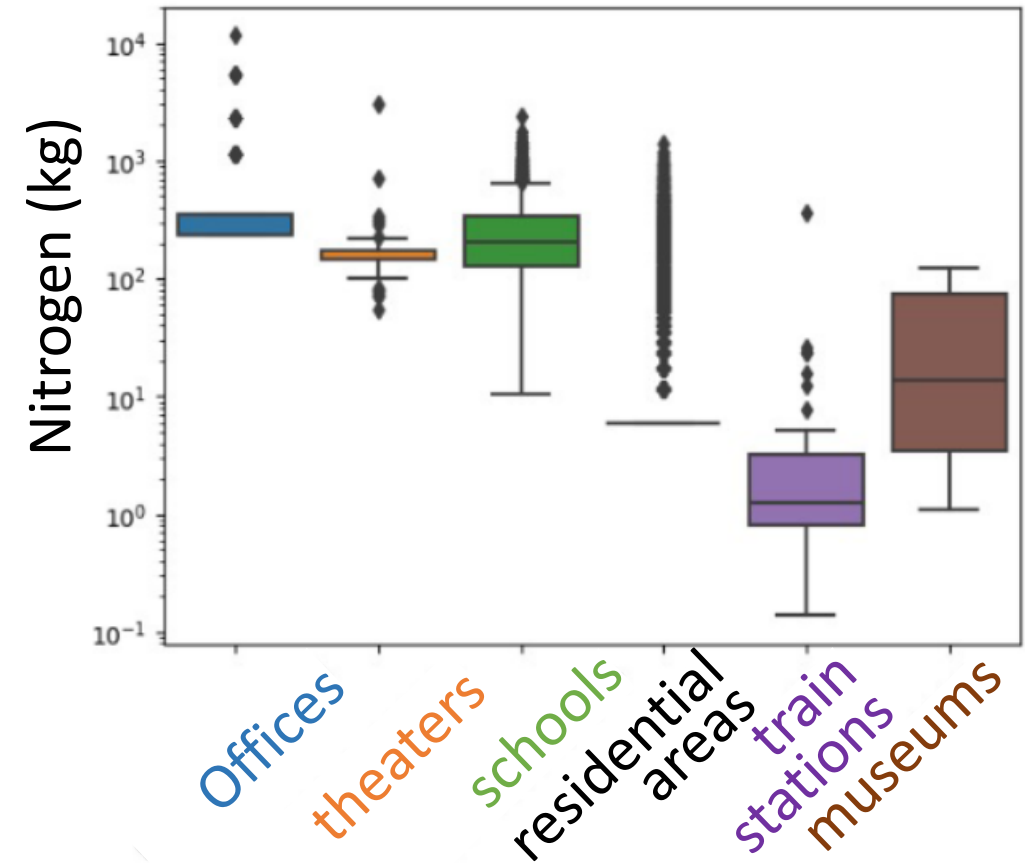
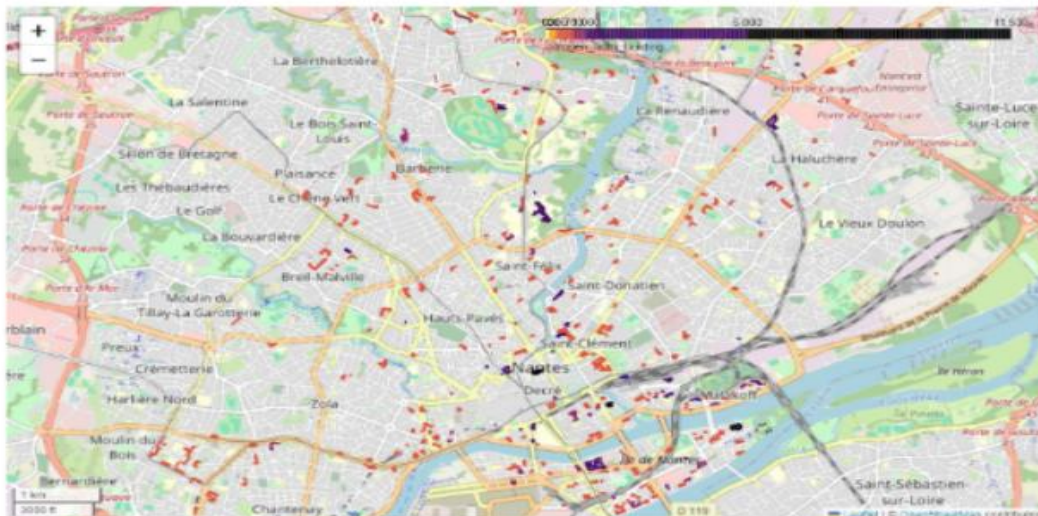
tons of N
per km²



But how?

CAFE project: optimize recovery (T. Fardet)

- Identify largest deposits in cities
- establish recovery scenarios
- LCA to assess impacts



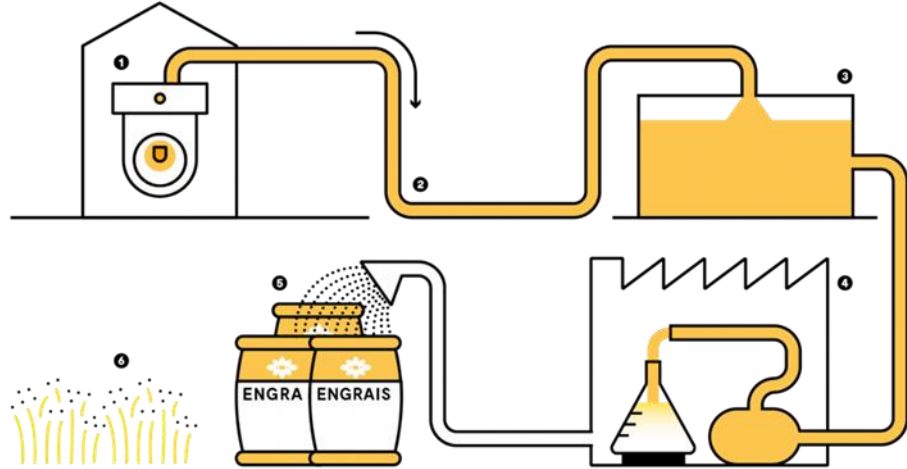


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Paris example



P&Ma



47 000 L/y:
Used for green
spaces in Paris

Saint-Vincent-de-Paul neighborhood - Paris
2018-2020 then 2024: 1st project for whole
neighborhood (600 dwellings)
with urine diversion and production of Aurin (nitrification & distillation)





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Conclusions



- **10% of N from WWTPs reused** in agriculture in France
- Most N excretions could be spread at < 10 km
- Need for low-tech concentration/recycling systems
- But also moderation (meat consumption)

Hvala na pažnji!
Хвала на пажњи!