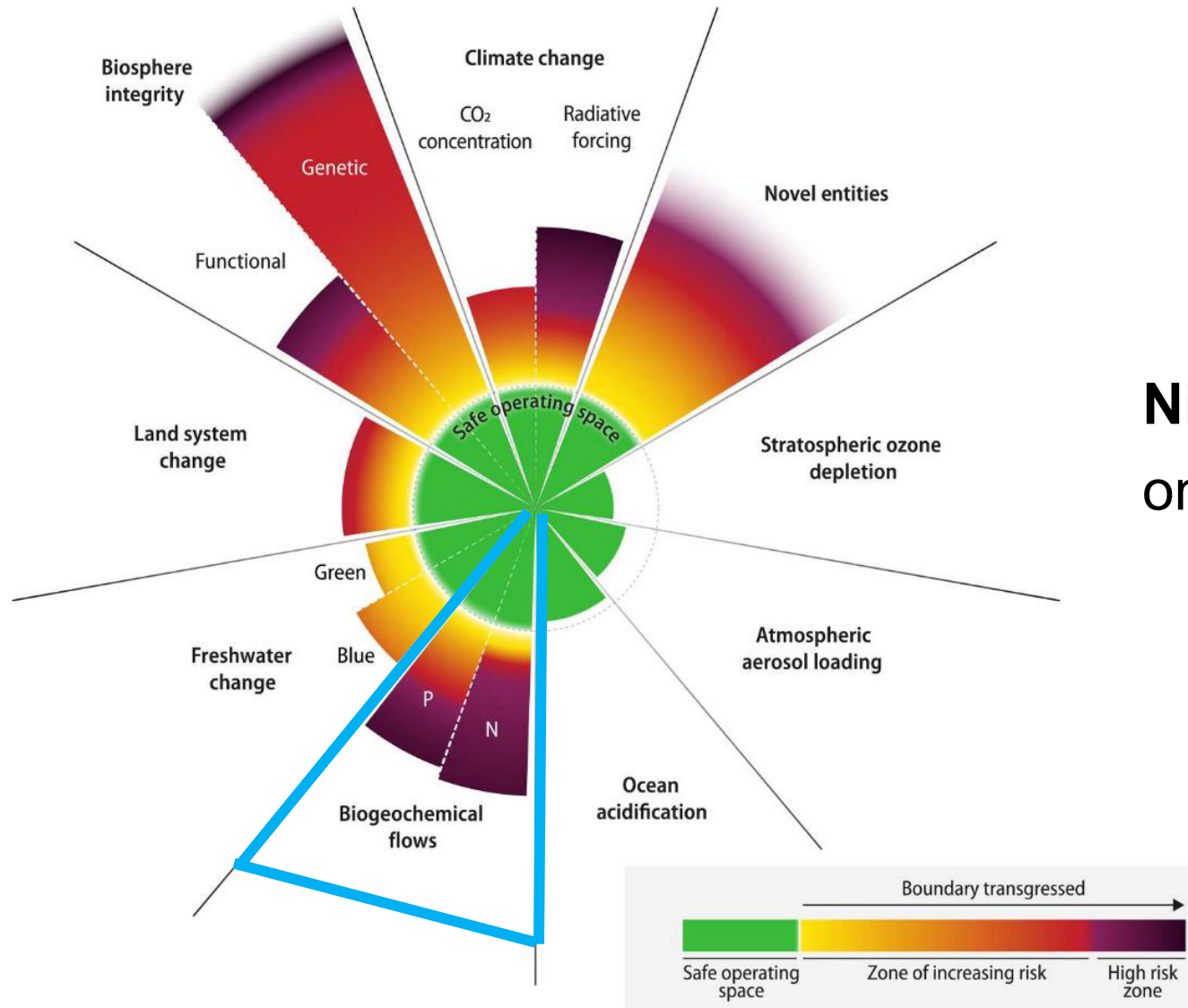


Planetary boundaries



Nitrogen and phosphorus cycles:
one of the six transgressed boundaries

The nitrogen path to our plates



→
 N_2

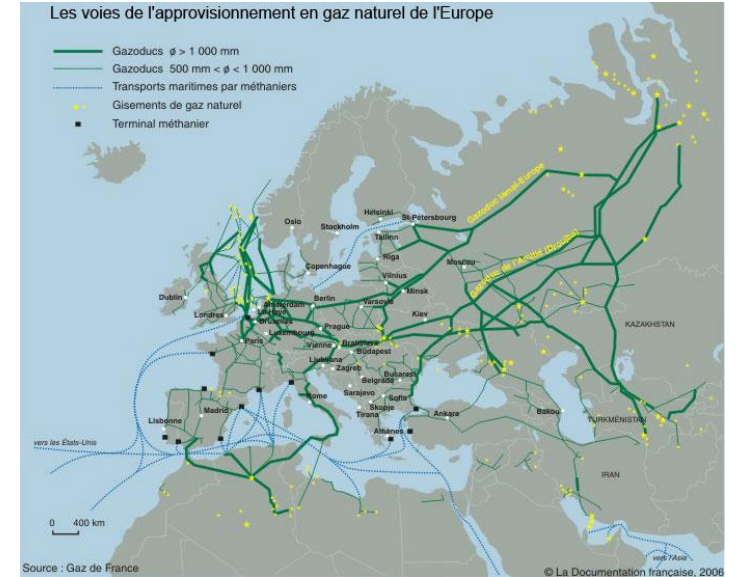
Haber-Bosch process



2.5% of greenhouse gases emissions in France

←

Methane (natural gas)



Chemical fertilizers ↓



→



→



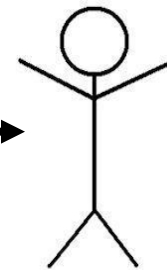
→



20-50 kg N



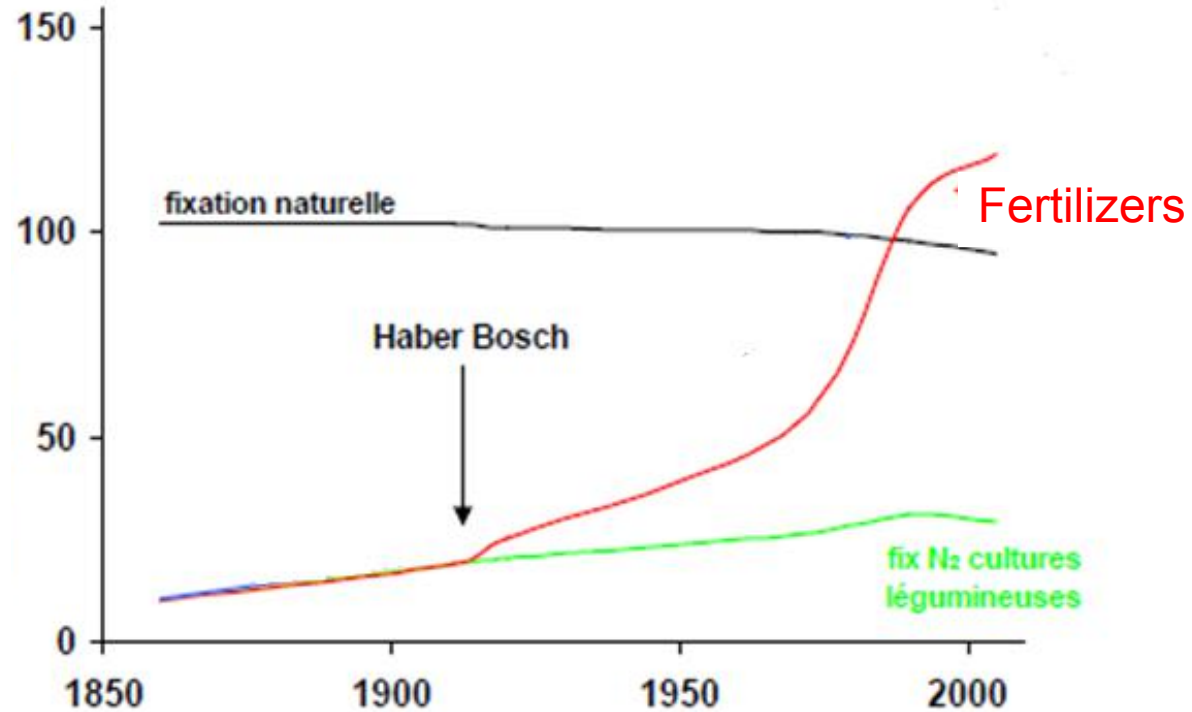
→



5 kg N

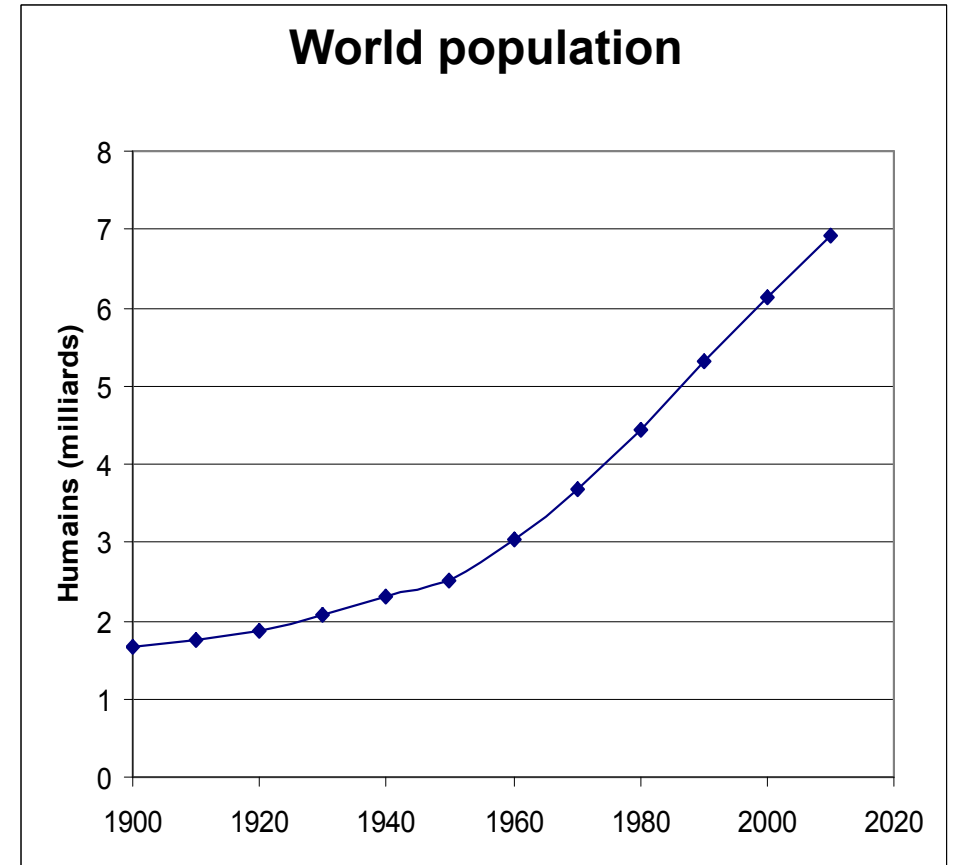
More than a revolution

Nitrogen introduction (TgN/y)



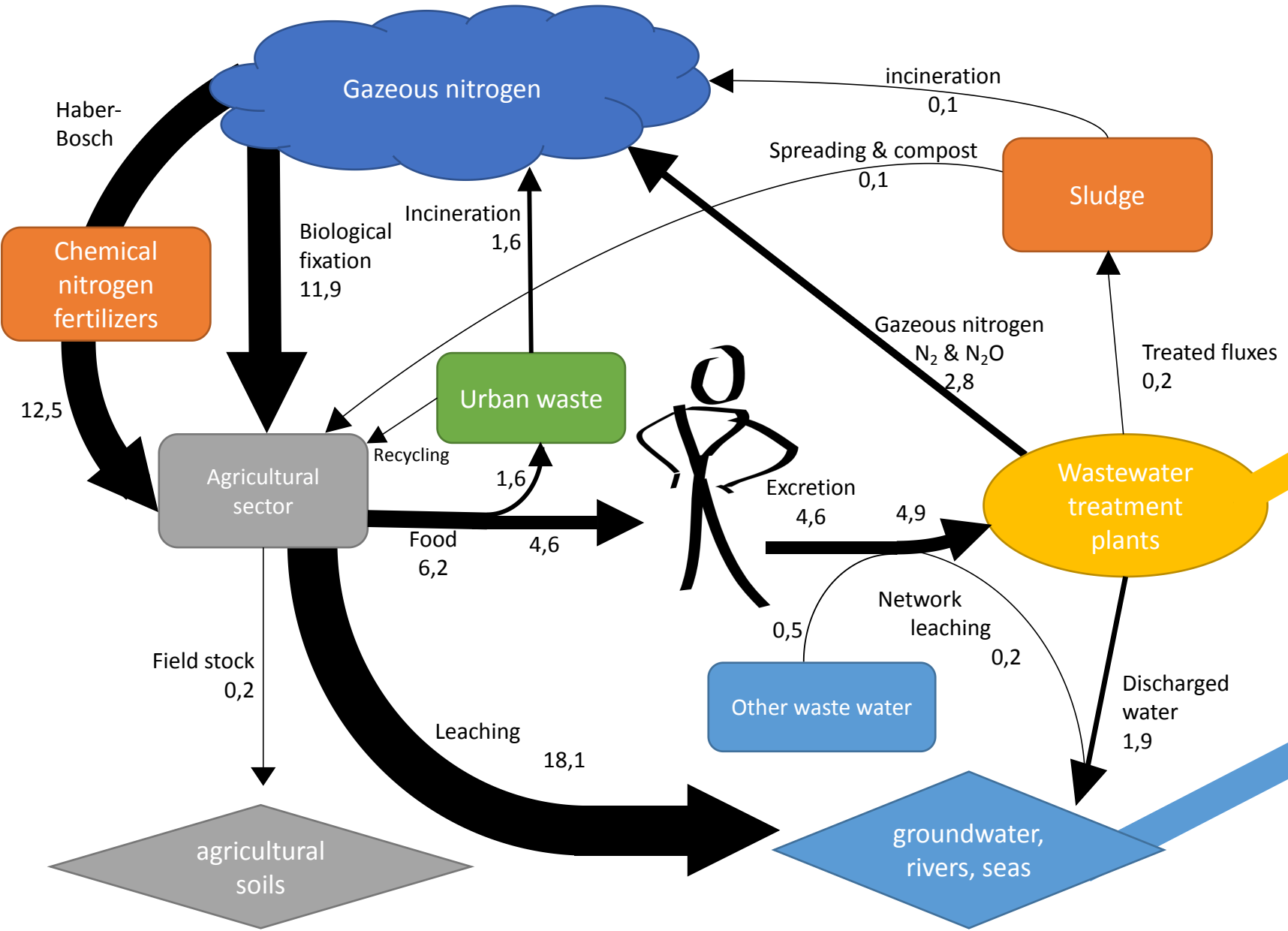
« Anthropocene »

(Paul Crutzen, 2002)



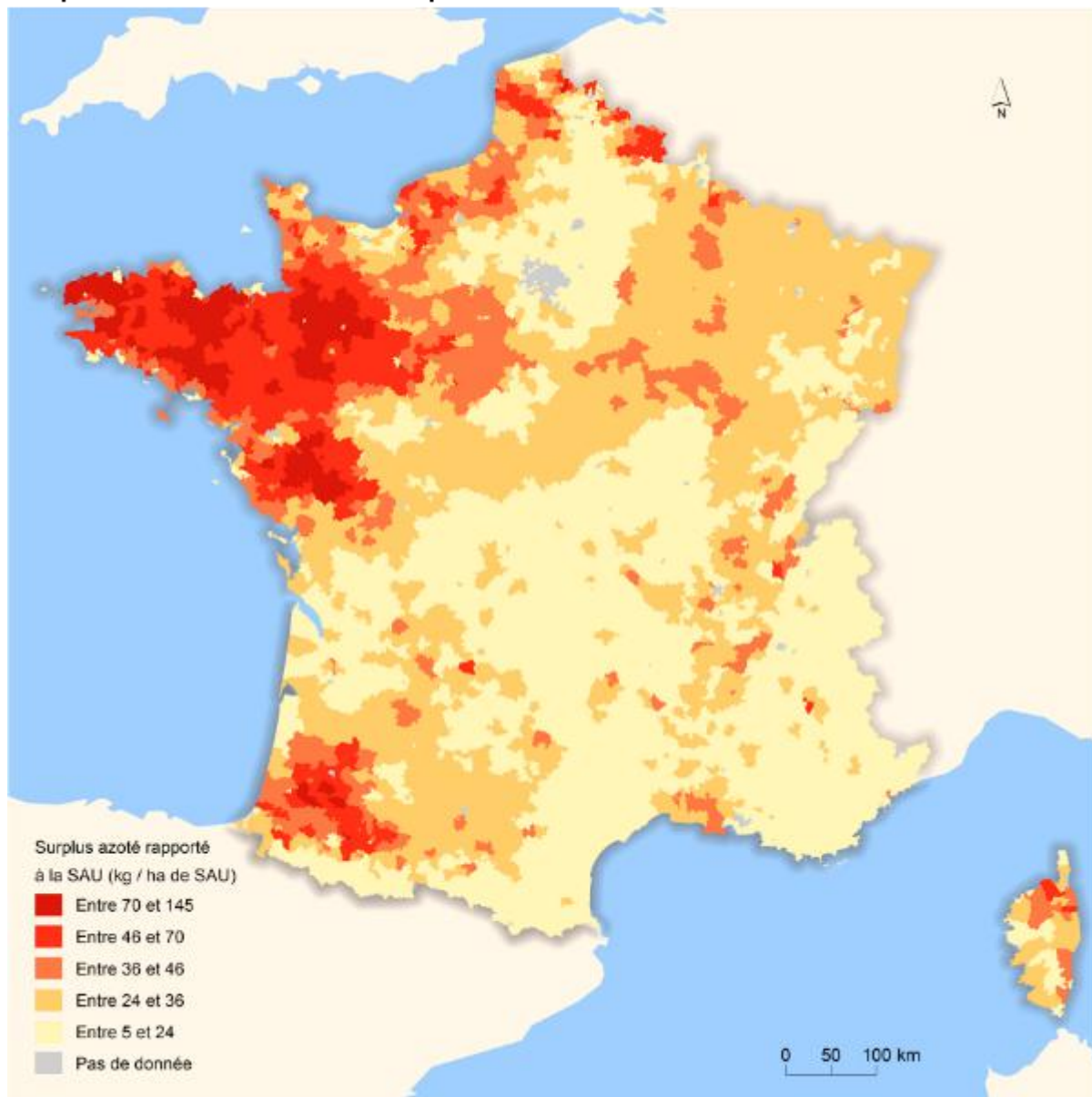
US Census Bureau ; ONU,
2012

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**

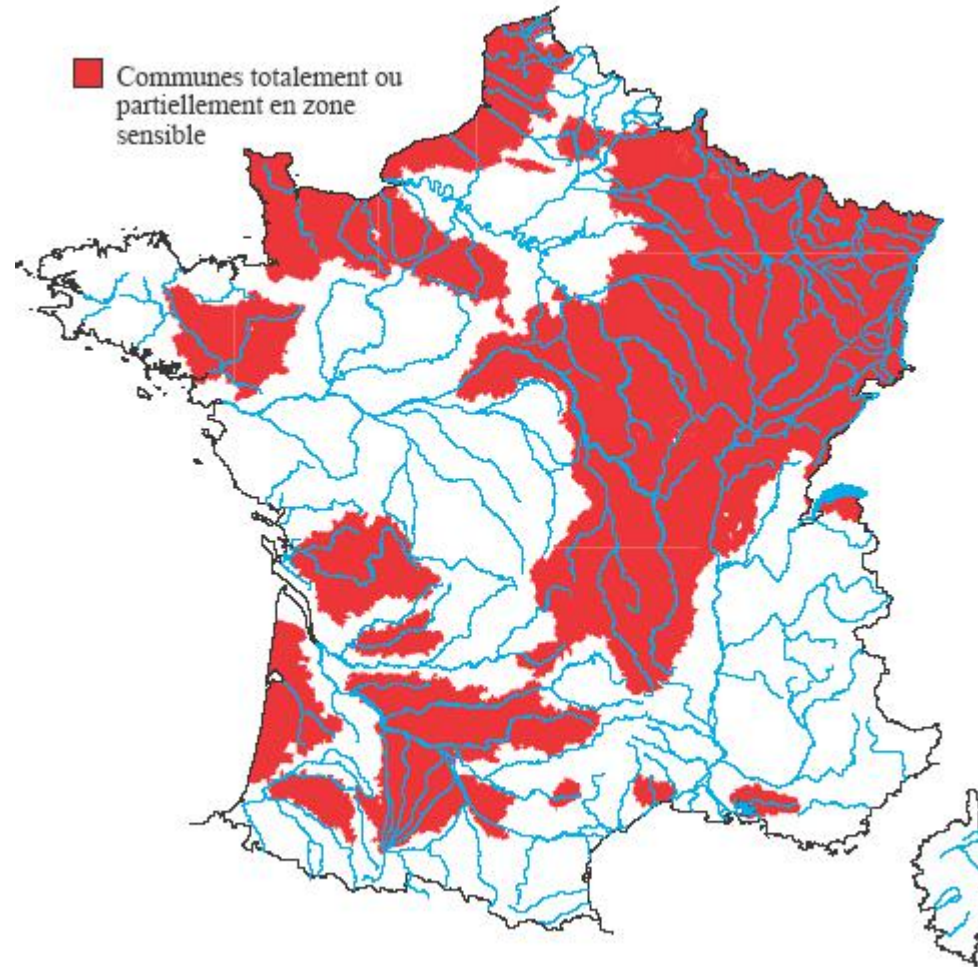
Sensitive to eutrophication: N & P discharges to be reduced

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

Sensitive areas

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

2006



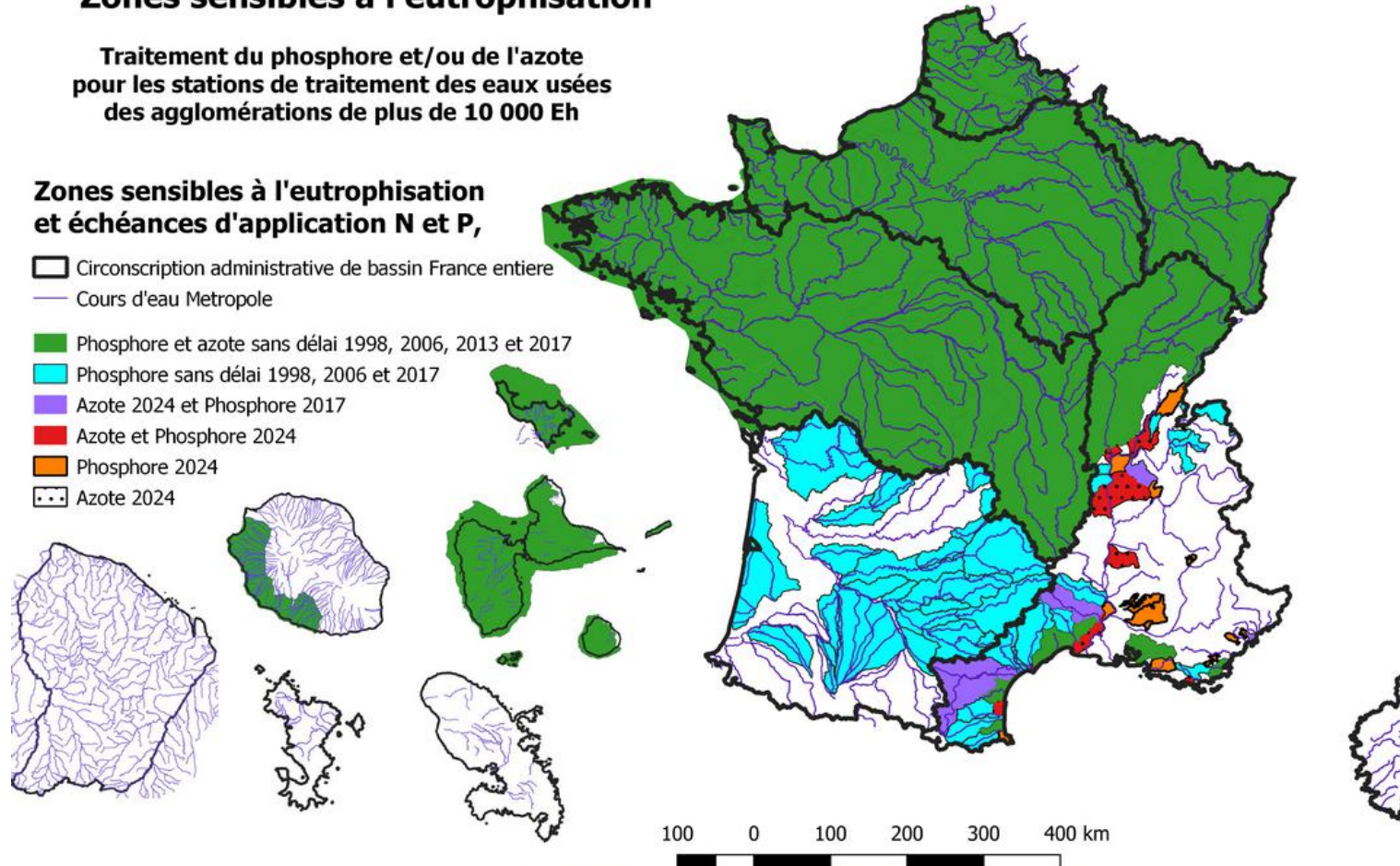
Sensitive areas

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,

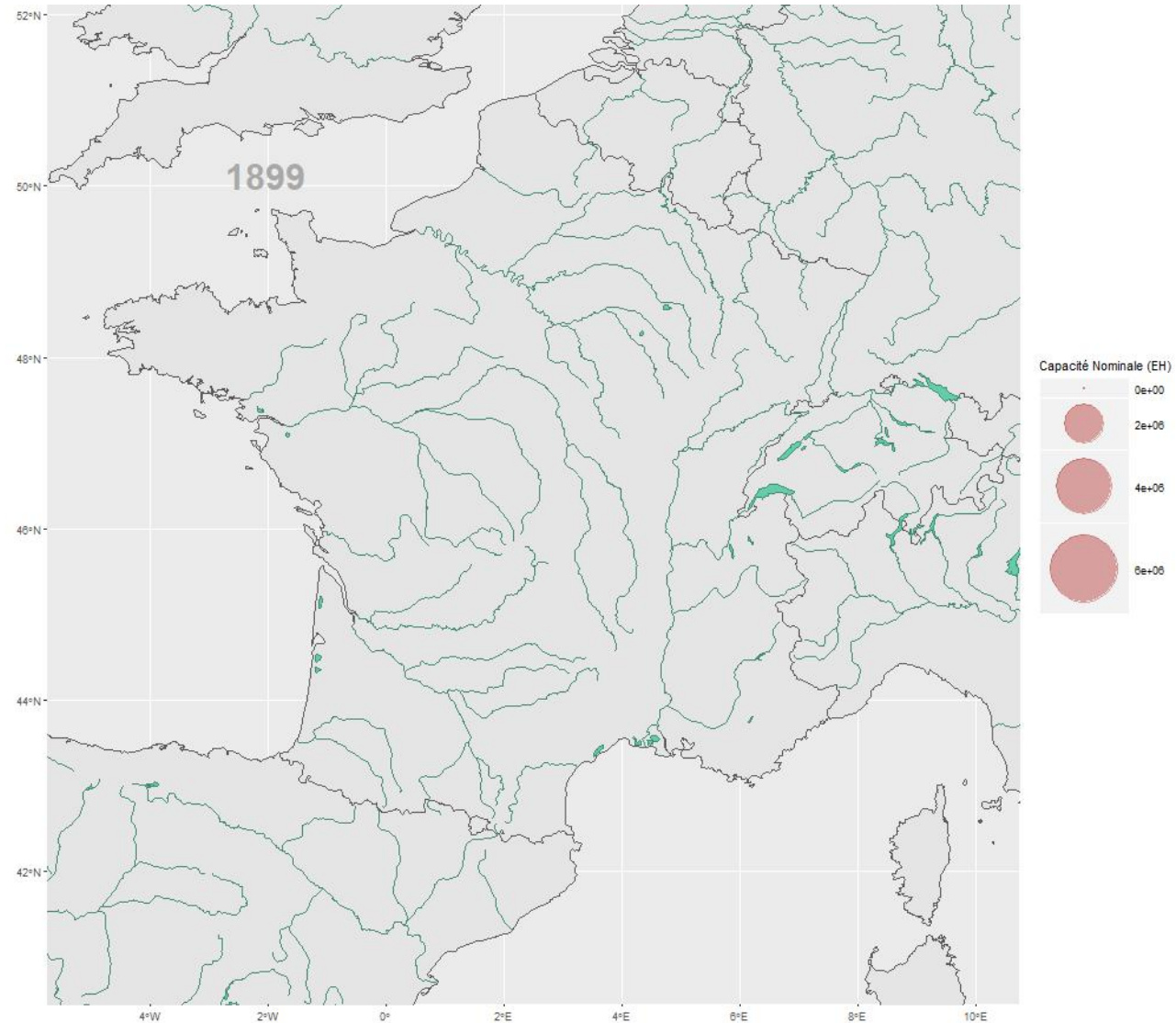
-  Circonscription administrative de bassin France entière
-  Cours d'eau Metropole
-  Phosphore et azote sans délai 1998, 2006, 2013 et 2017
-  Phosphore sans délai 1998, 2006 et 2017
-  Azote 2024 et Phosphore 2017
-  Azote et Phosphore 2024
-  Phosphore 2024
-  Azote 2024



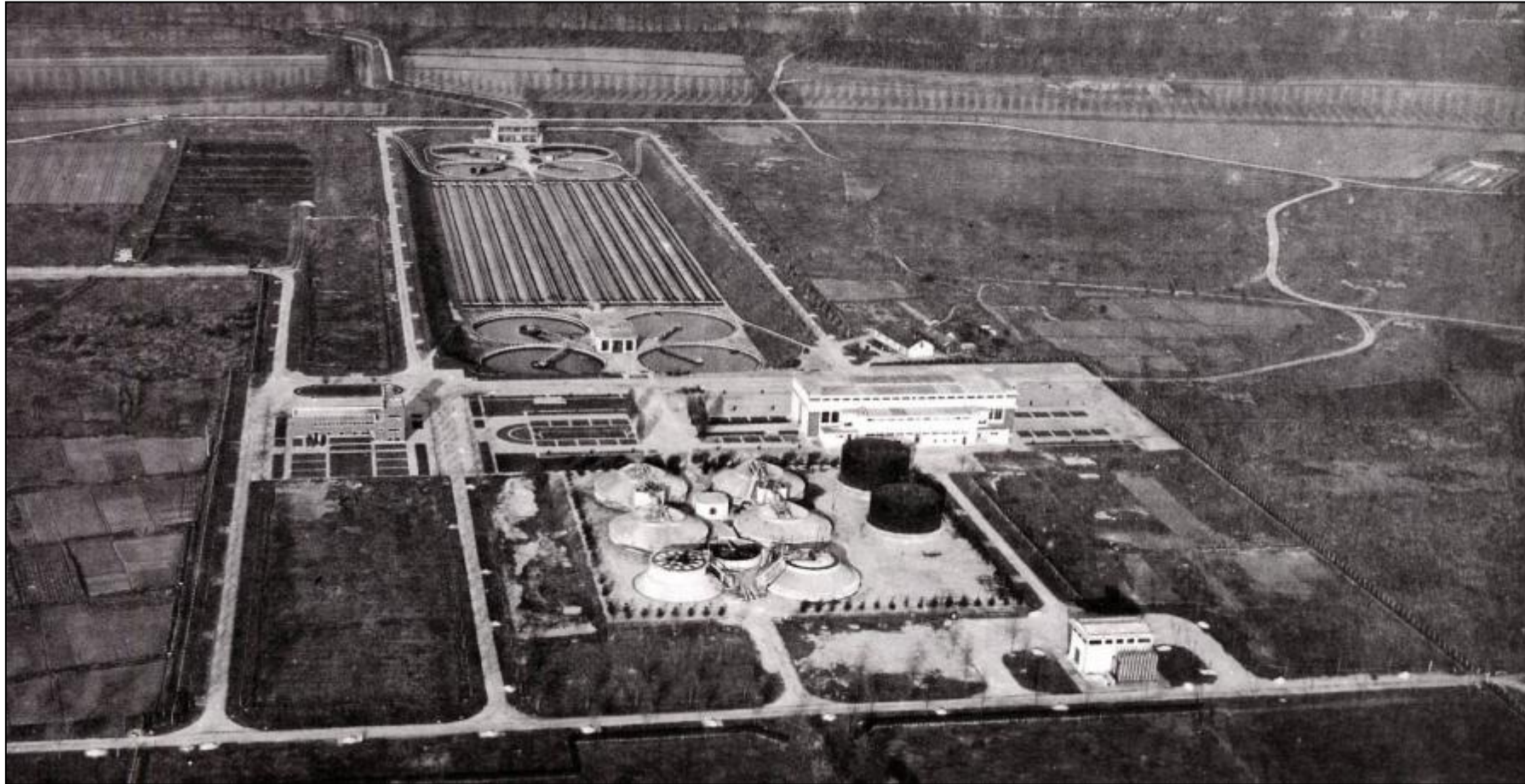
2020

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

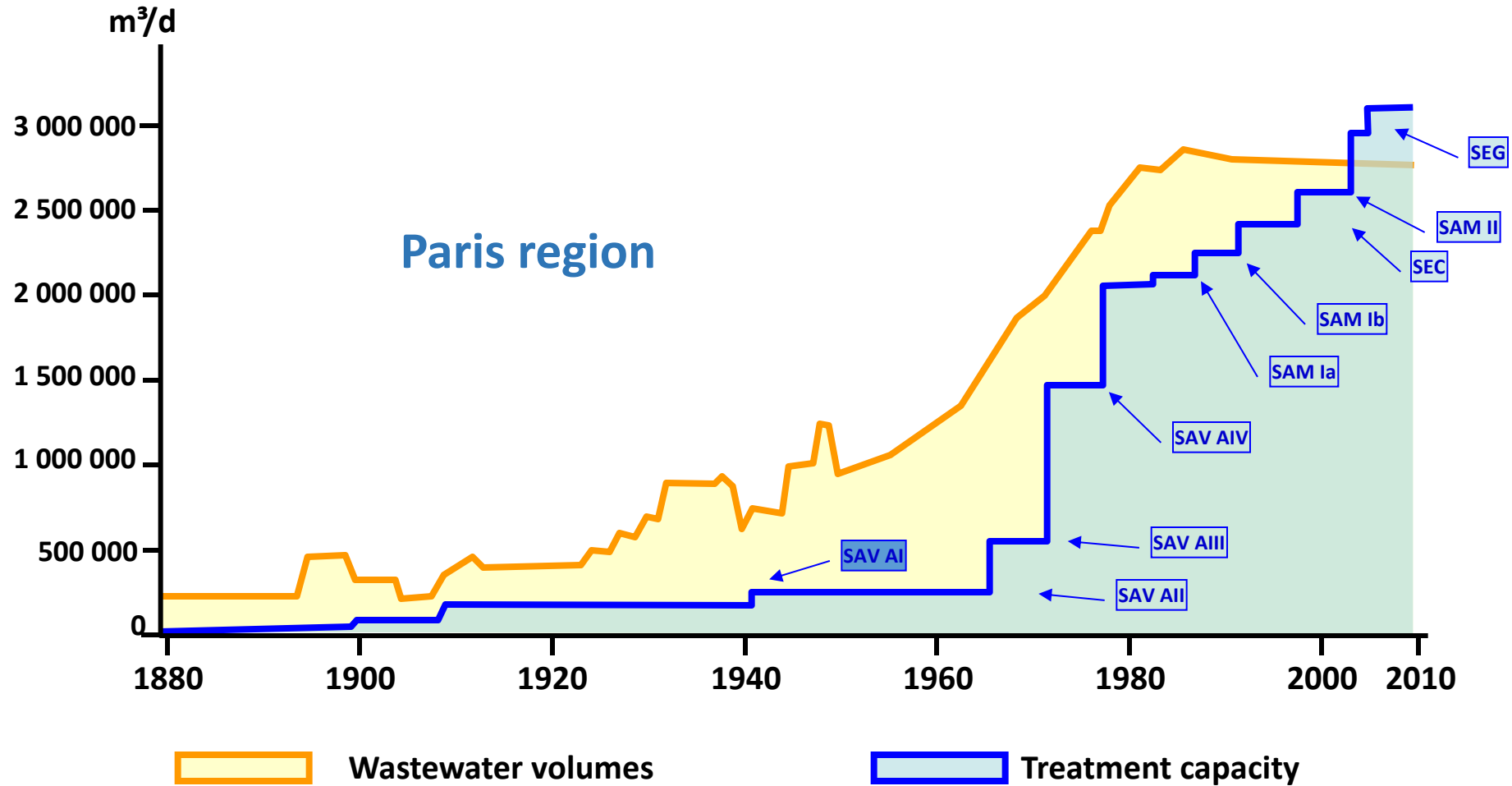
WWTPs built in France over the years



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).

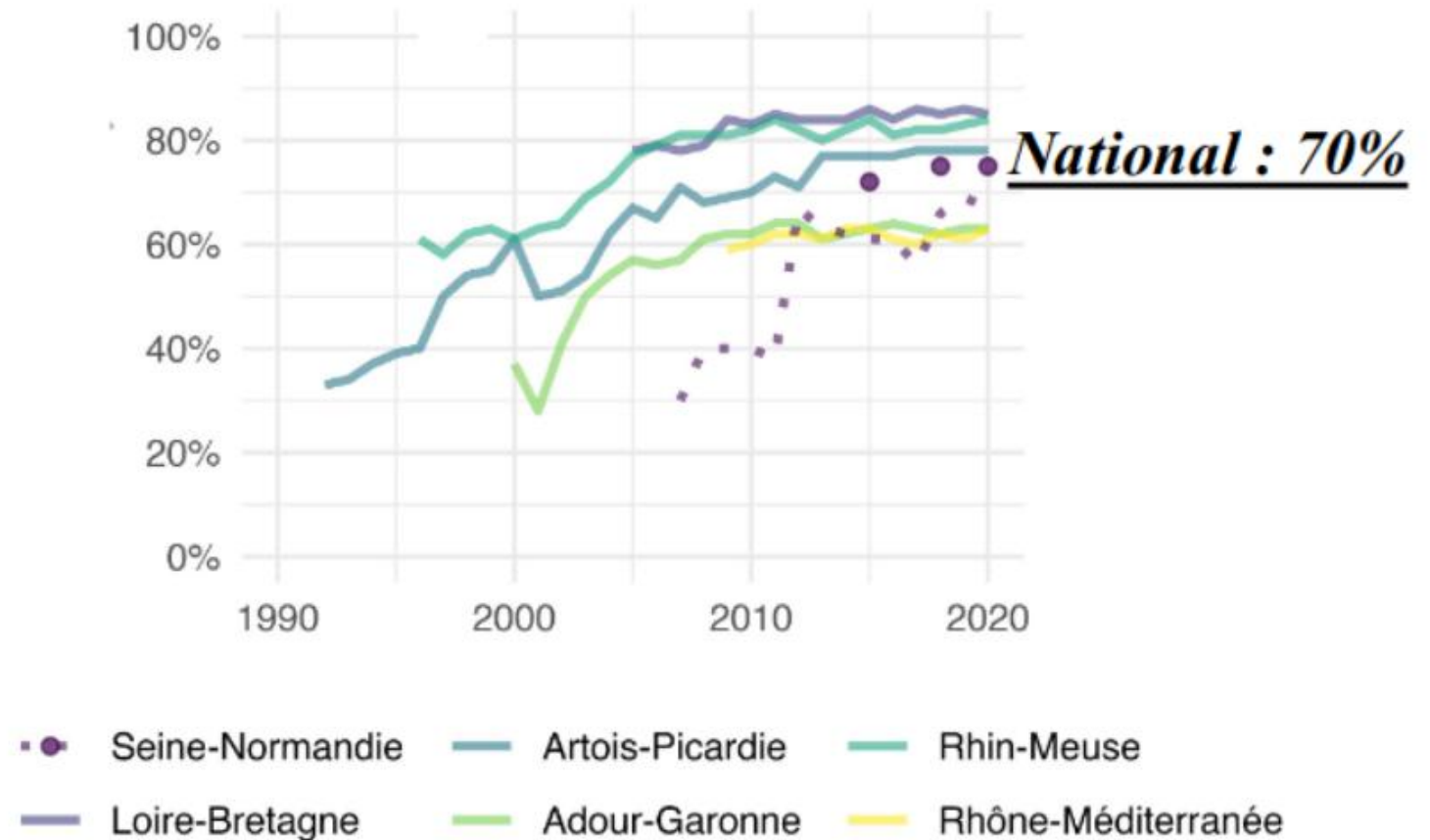
50 to 100 WWTPs each year! (for cities > 2000 inh.)

WWTPs efficiency

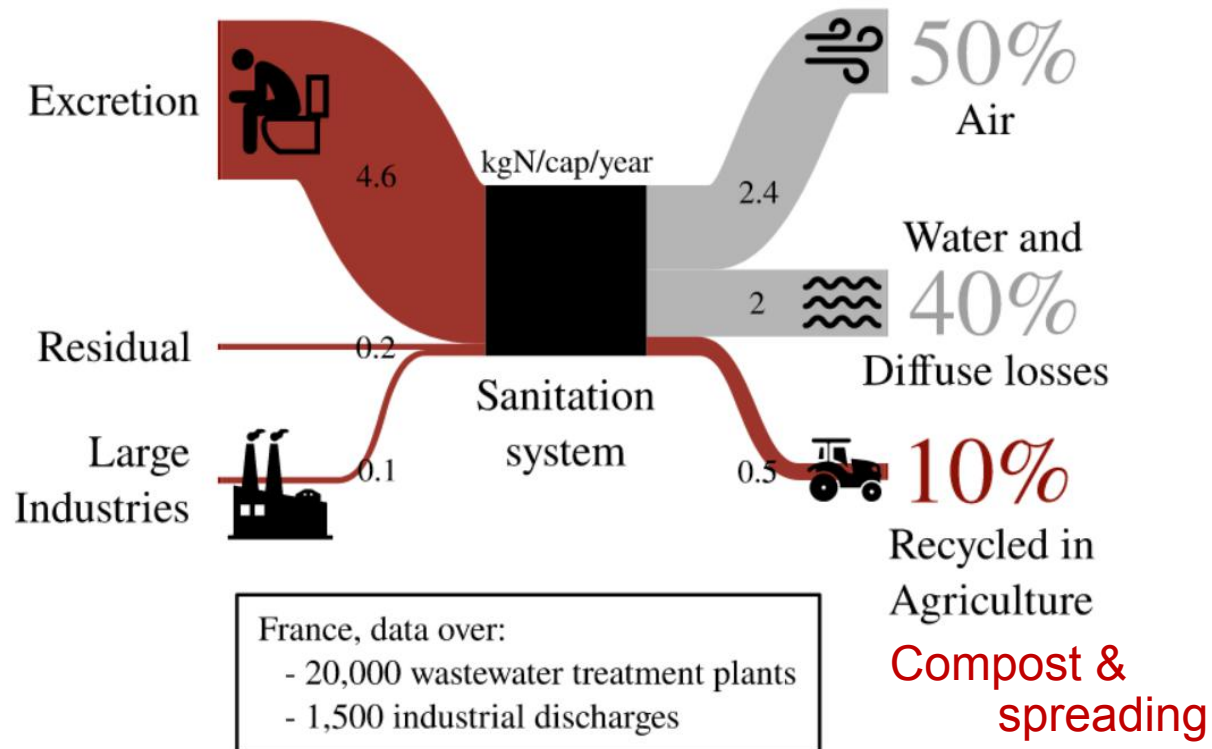
Large public database of french WWTP removal efficiencies freely available

<https://assainissement.developpement-durable.gouv.fr>

Nitrogen removal efficiencies For the 6 French Water Agencies



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}

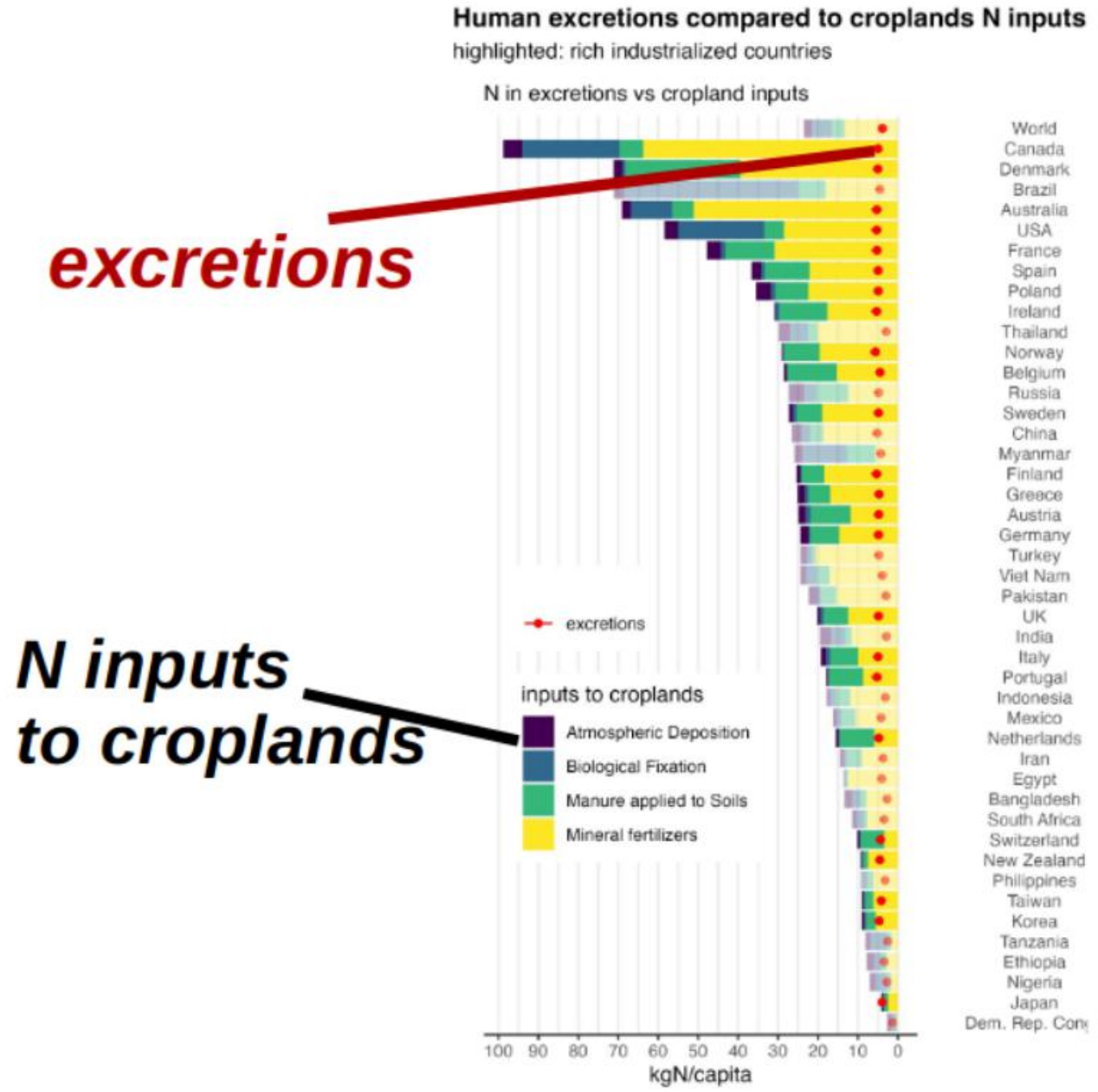
<https://doi.org/10.1016/j.scitotenv.2023.168978>

Thomas Starck PhD thesis

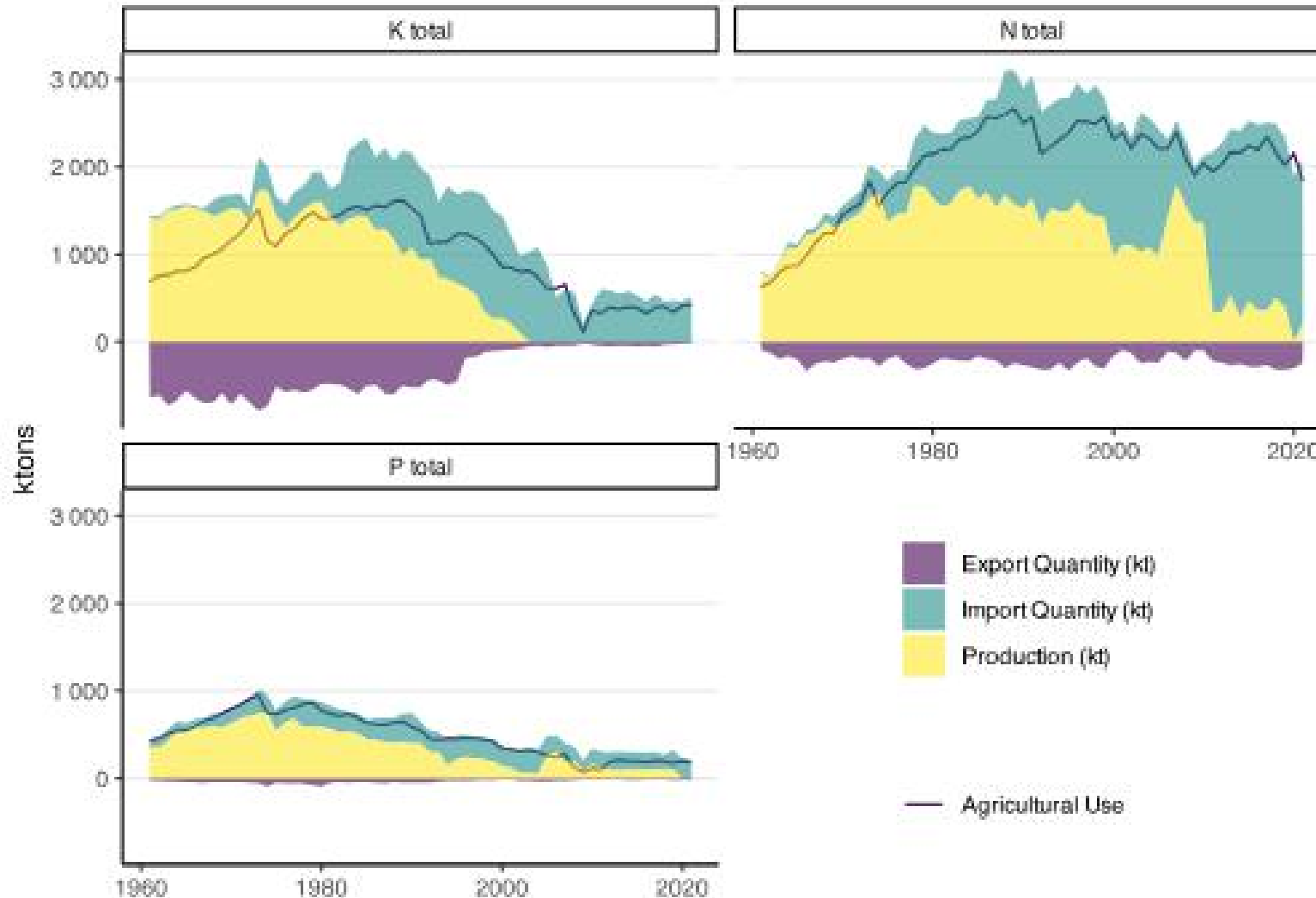
What is the potential of human N excretions for fertilization?

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

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



Fertilizer usage in France



Mostly imported nowadays

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

How much fertilizer can be replaced by urine?

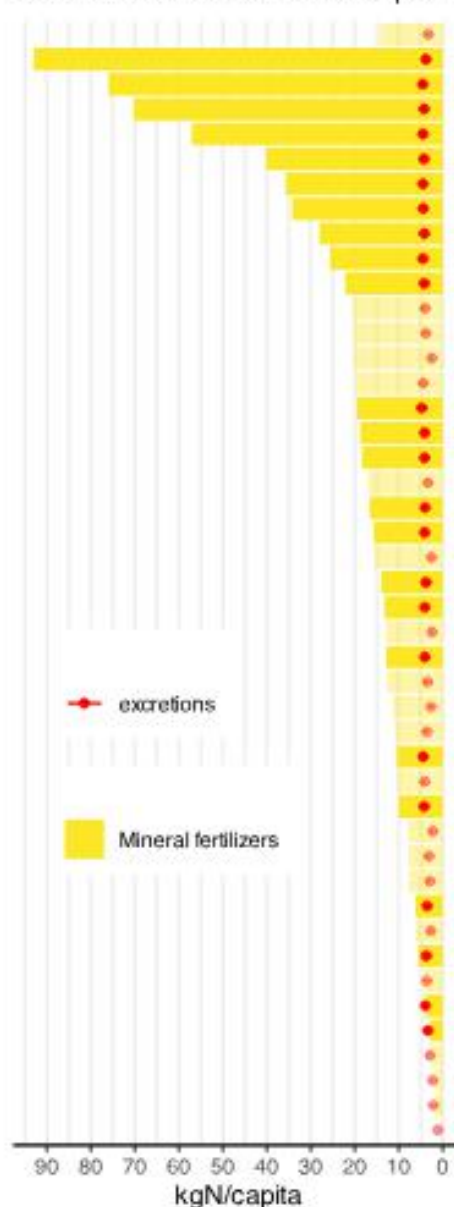
15% in France
25% worldwide

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

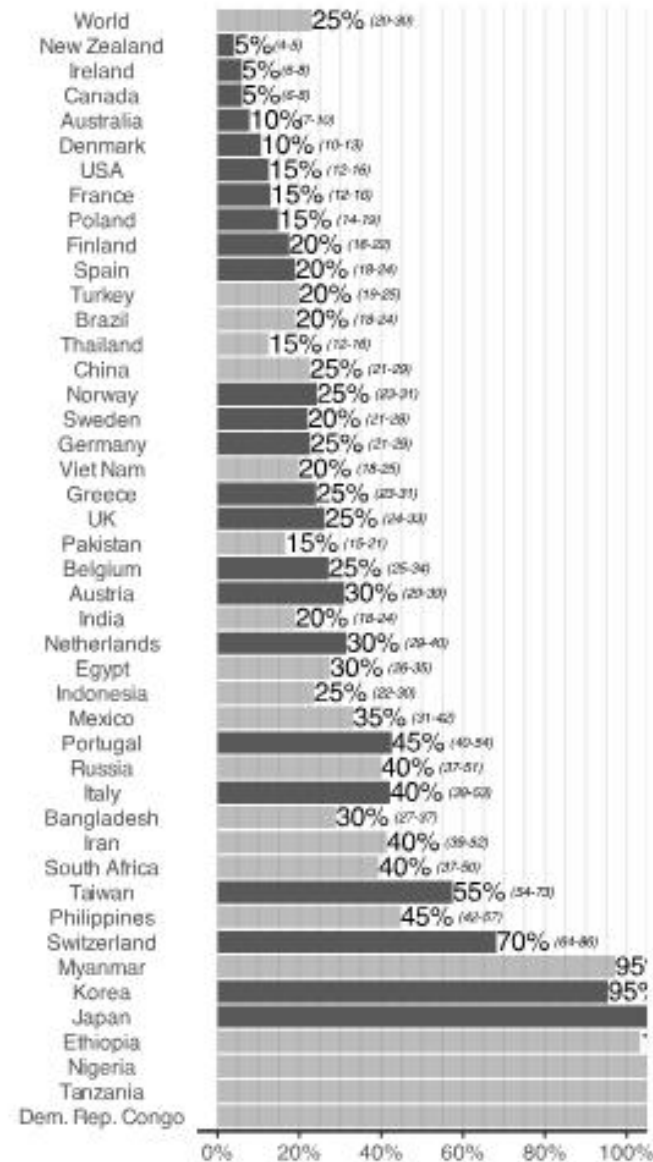
Maximum potential substitution of synthetic fertilizers by human urine

highlighted: rich industrialized countries

N in urine and fertilizers consumption



% of fertilizers replaced by urine



based on FAOSTAT data for 2015-2020

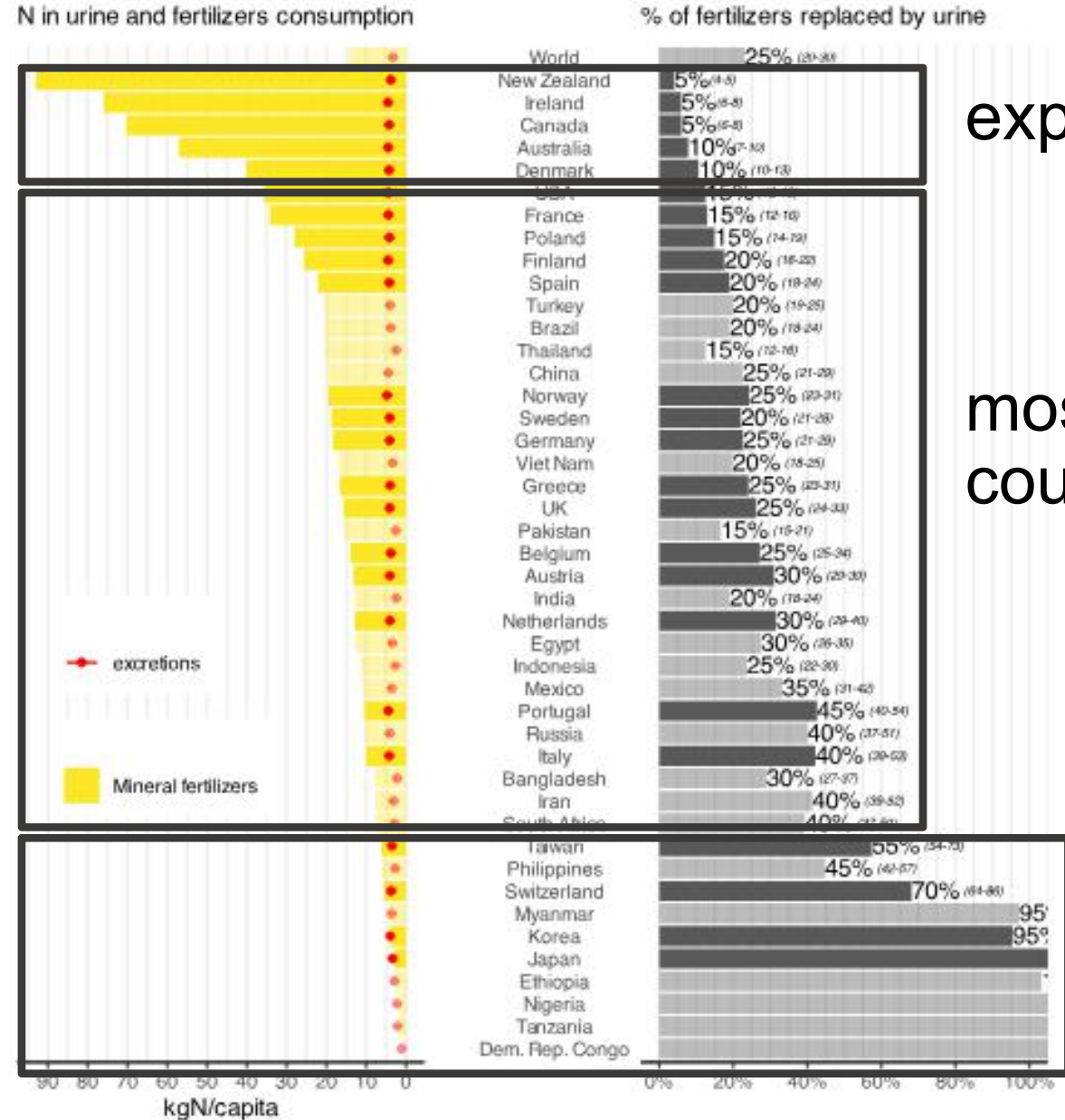
How much fertilizer can be replaced by urine?

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



exporters

most countries

sub-saharan Africa & rich industrialized Asia



Most N used for animal production in rich industrialized countries

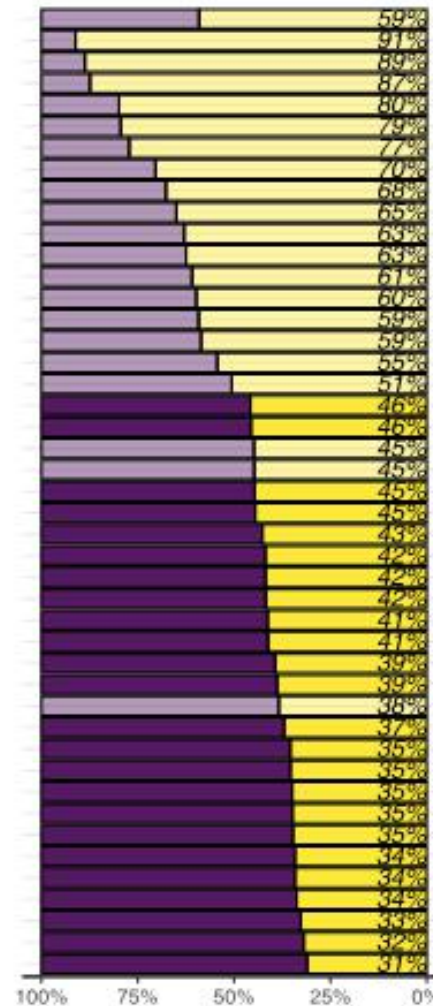
<https://thomas-starck.github.io/potential-human-excretions-fertilization/potential.html>

Repartition of vegetal and animal products in N food supply

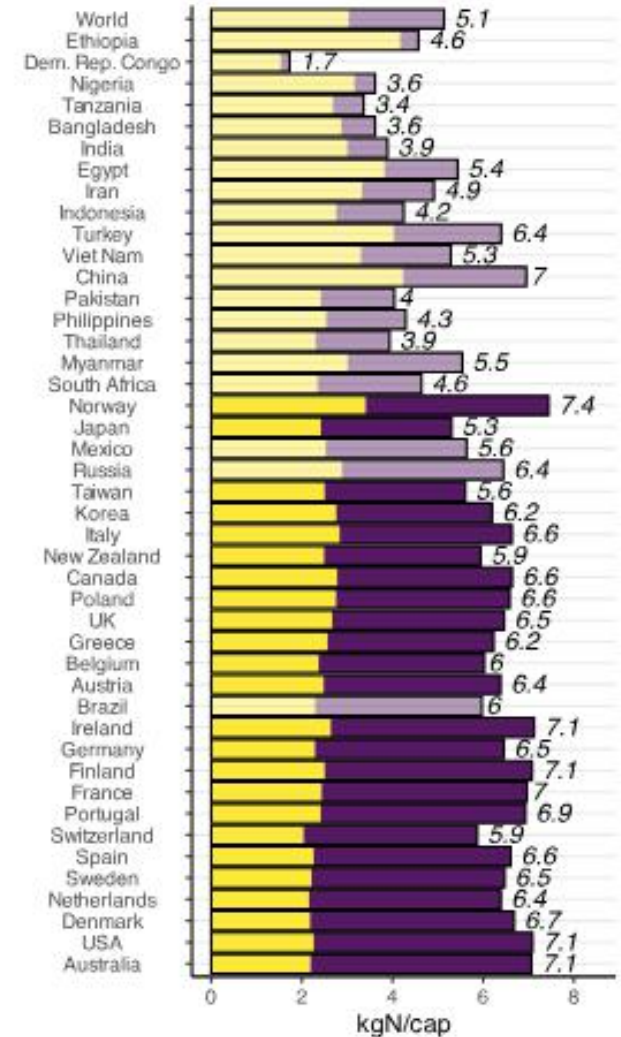
highlighted: rich industrialized countries

relative shares

■ animal ■ vegetal

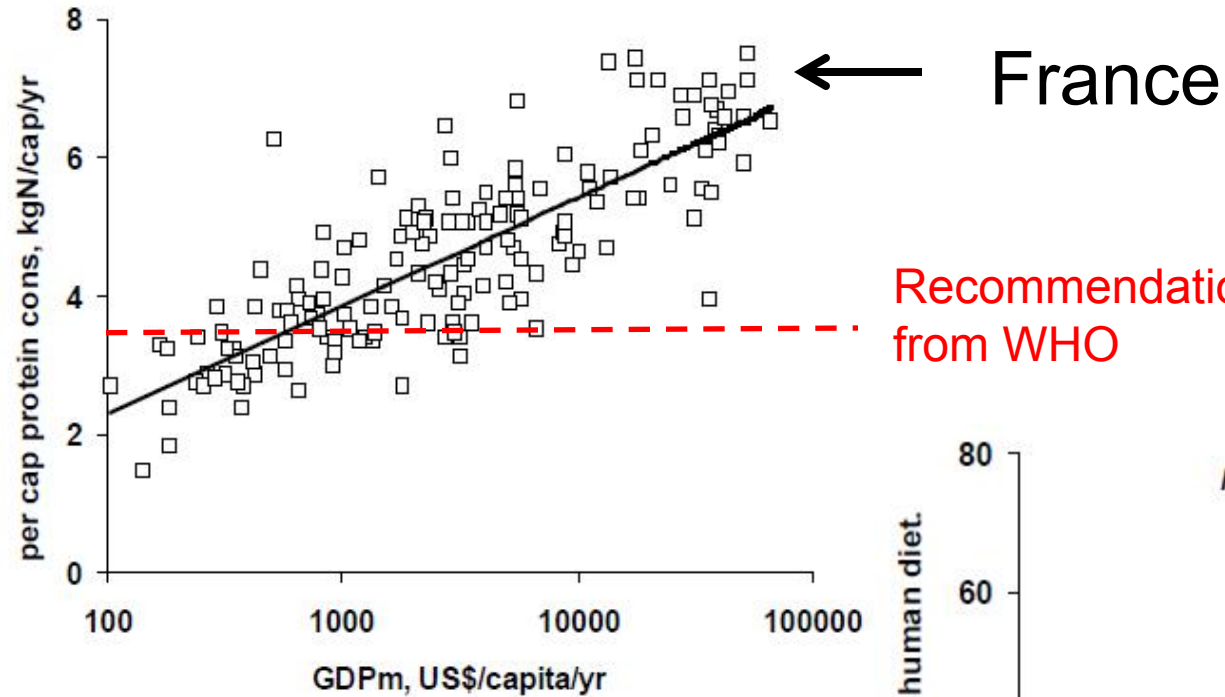


absolute quantities

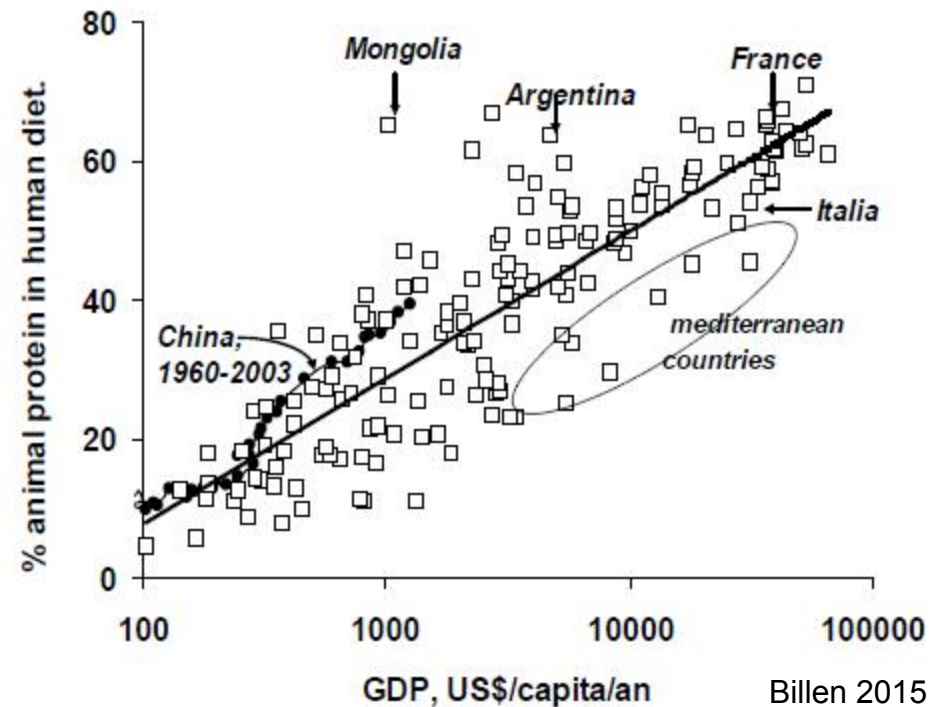


based on FAOSTAT data for 2015-2020

Protein consumption



1. Limit the consumed amounts
2. Favor vegetal proteins



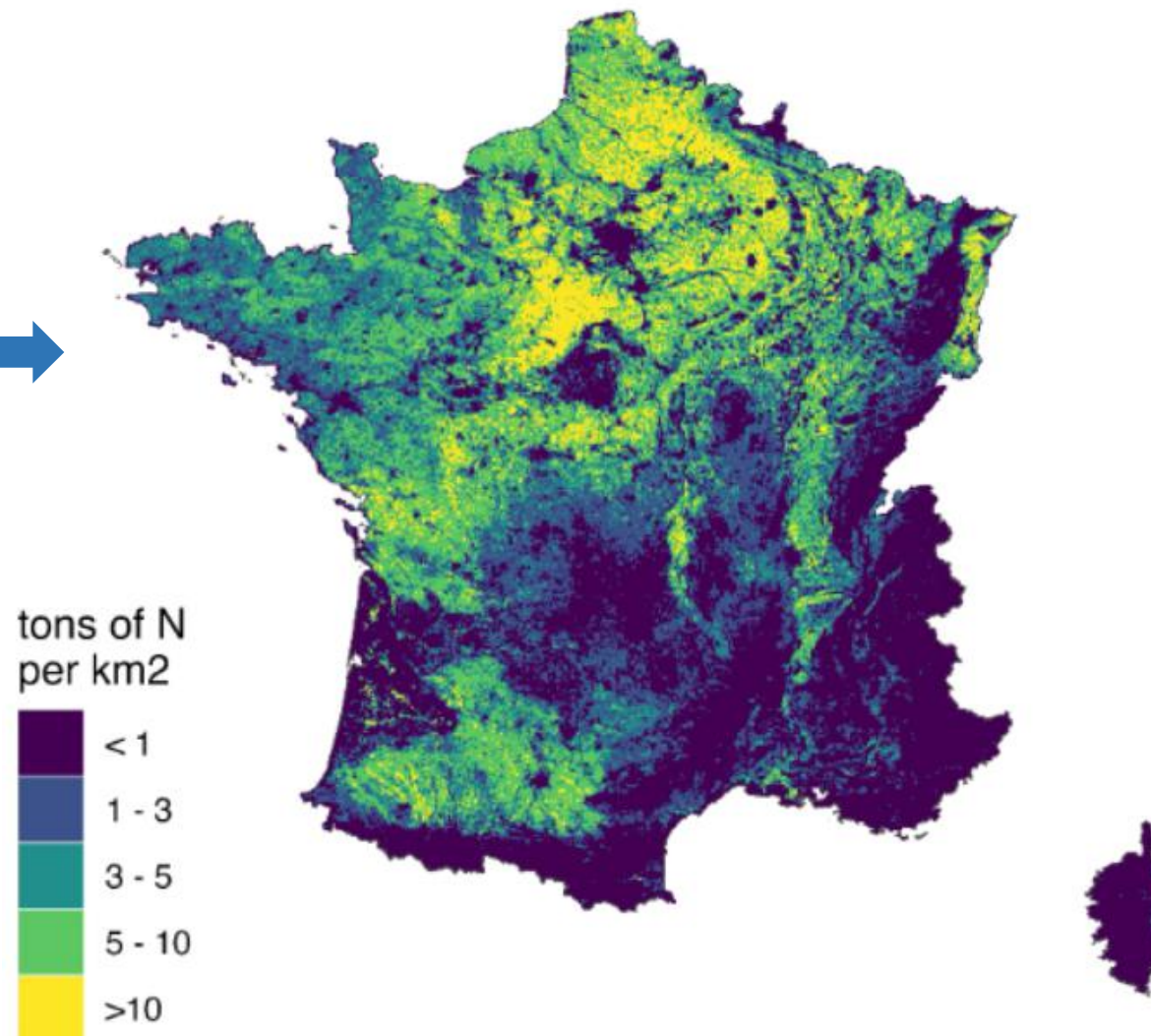
Where can we use source-separated urine?

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



Mineral fertilization

(~2000 ktN)

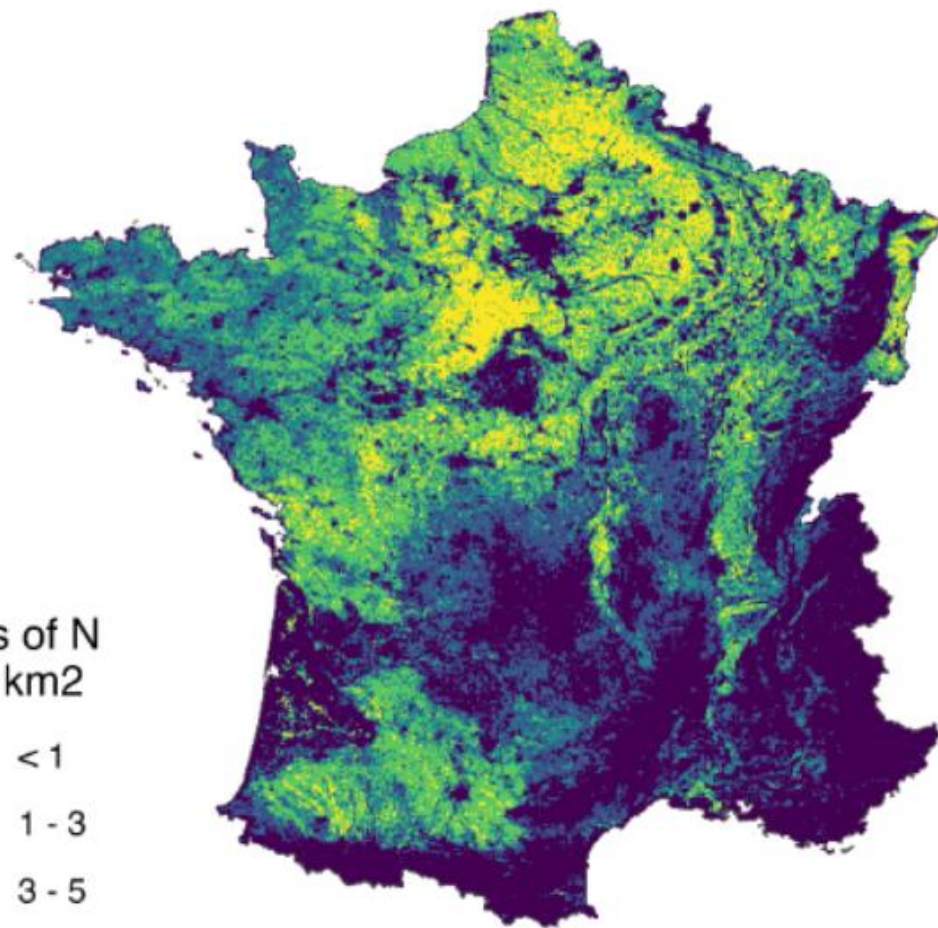


Where can we use source-separated urine?

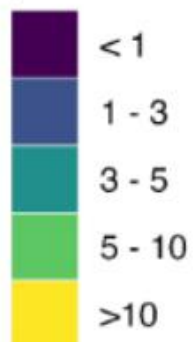
Mineral fertilization

(~2000 ktN)

N excretions



tons of N
per km²



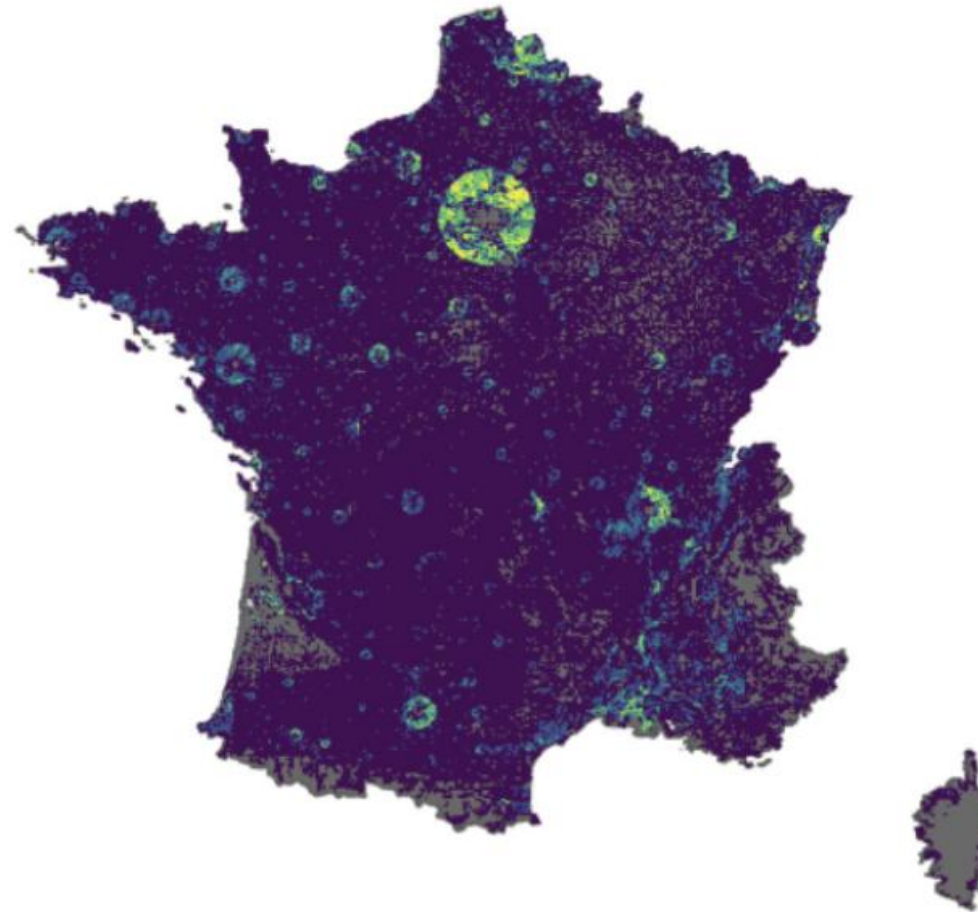
population data + N ingestion

Where can we use source-separated urine?

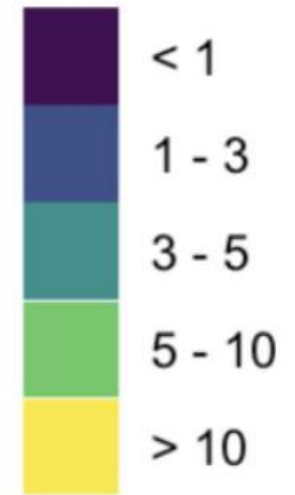
fertilization with excretions

Algorithm to substitute mineral N by human excretions on neighbouring parcels

Most excretions could be spread at < 10 km!



tons of N per km²

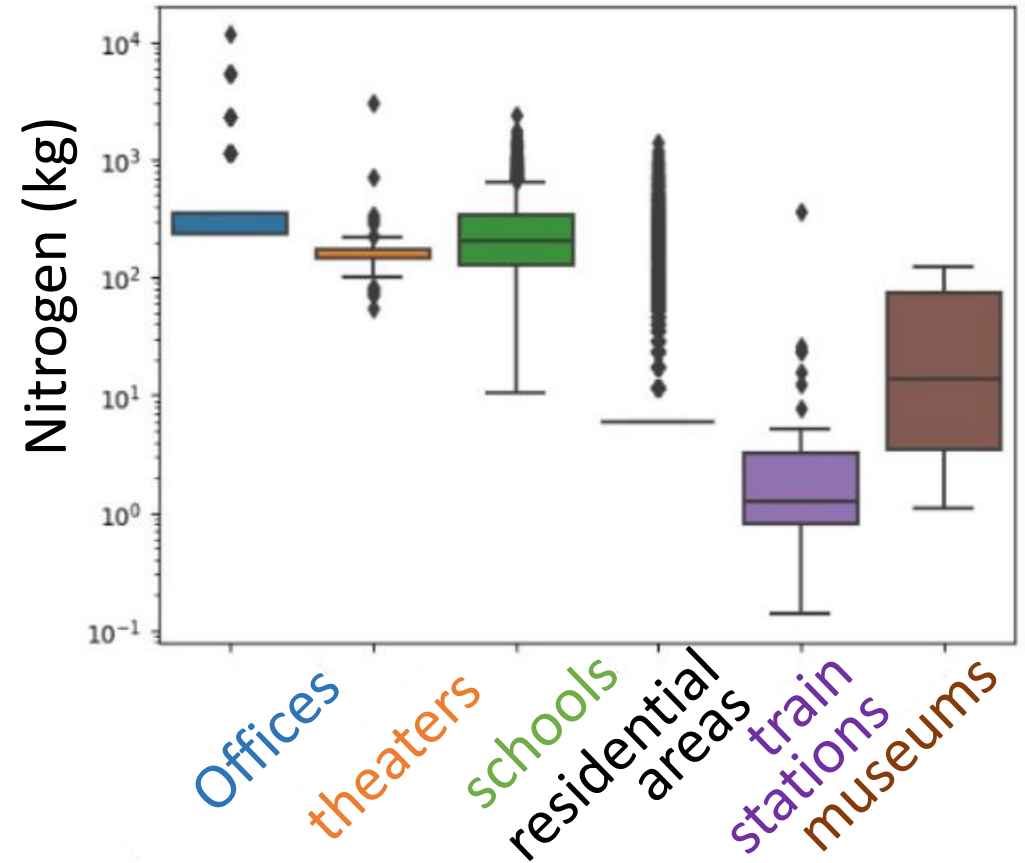
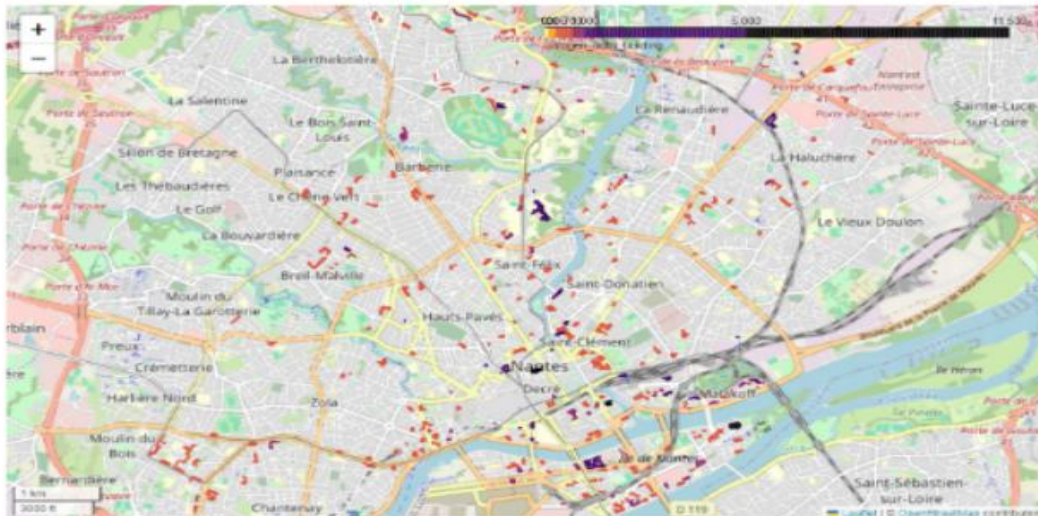


But how?

CAFE project: optimize recovery

(T. Fardet)

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



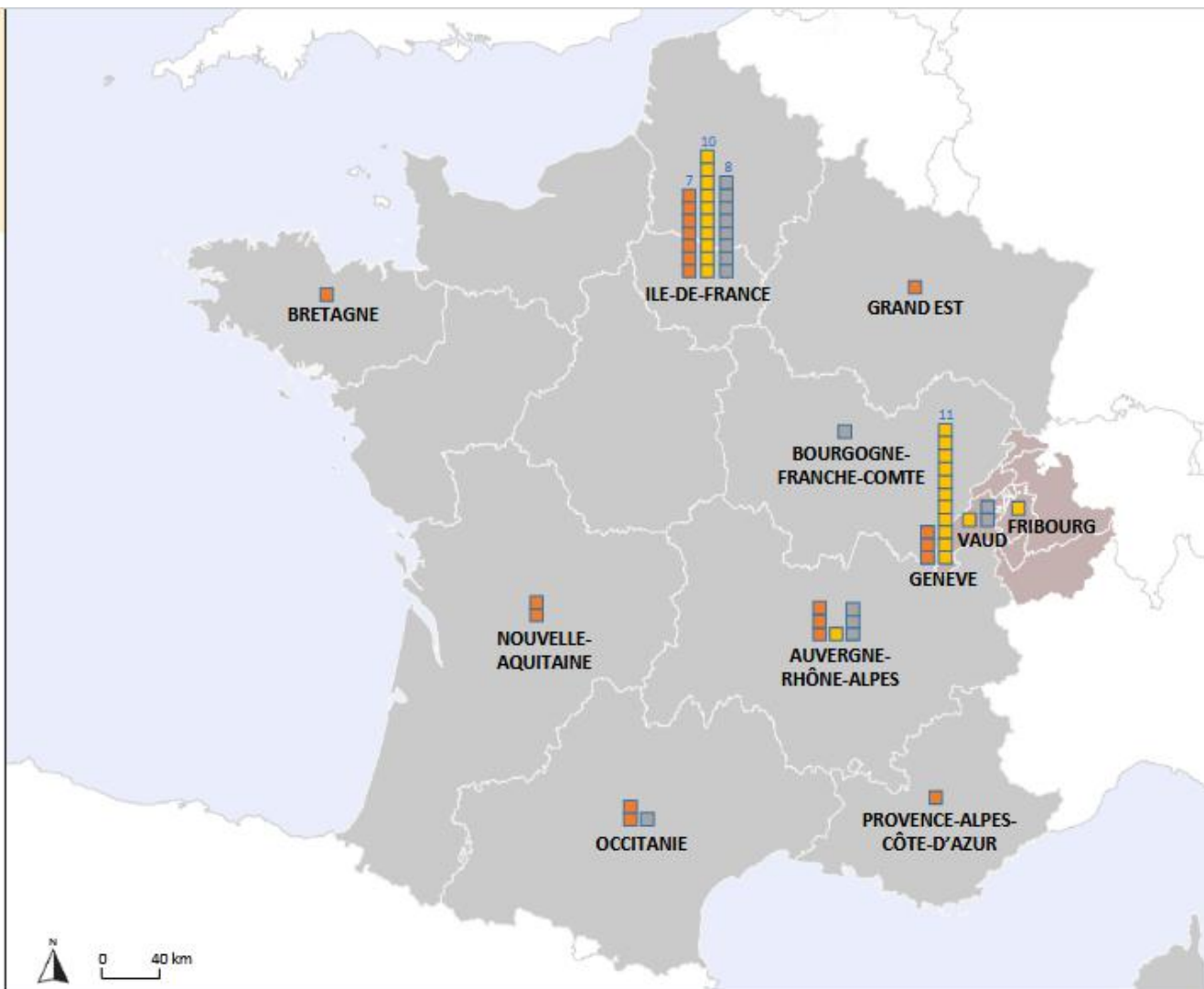
Etat des lieux des projets urbains de gestion séparative des excréments dans des bâtiments collectifs identifiés en France et en Suisse romande en 2023

Projets identifiés par régions (France) et par cantons (Suisse romande), selon leur état d'avancement :

- Réalisés et en fonctionnement
- Validés et/ou en construction
- A l'étude

Note : les projets présentés sont issus d'un travail de recensement effectué par l'équipe OCAPi non forcément exhaustif et encore en cours. Si vous connaissez un projet, en France ou en Suisse, qui n'est pas sur la carte et que vous souhaitez communiquer à son propos, merci de prendre contact à l'adresse suivante : ocapi@enpc.fr.

Auteur : A. Joveniaux, OCAPi/LEESU-ENPC, 2023. Source : OCAPi et Aneco.



Utiliser l'urine humaine en agriculture

Fiches pratiques



Seuls les urinoporteurs ayant un faible potentiel de volatilisation peuvent être éparpillés avec un pulvérisateur.

OCAPi



Quel intérêt pour la **séparation à la source** dans la gestion des eaux usées domestiques en France ?

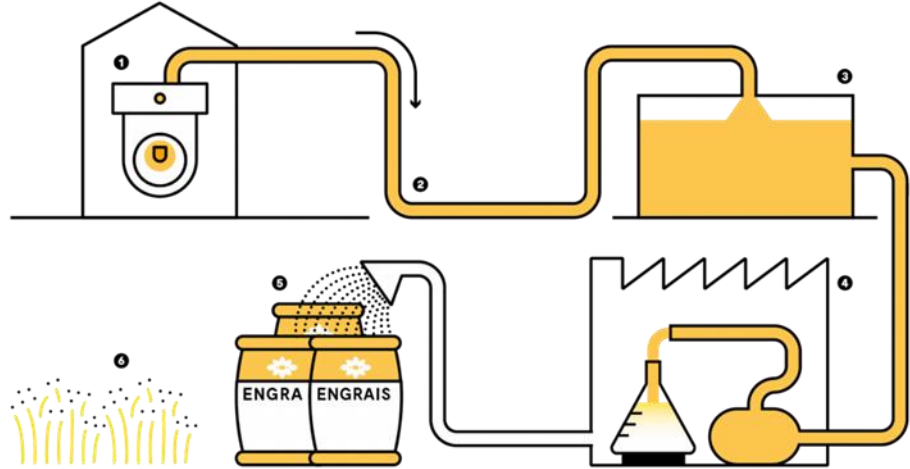


Operational guides at www.leesu.fr/ocapi/bibliotheque/bibliographie 26

Paris example



P&Ma



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



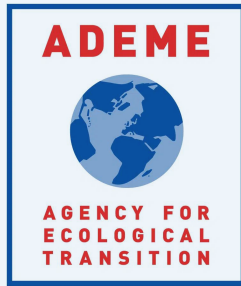
Saint-Vincent-de-Paul neighborhood - Paris
2018-2020 then 2024: 1st project for whole
neighborhood (600 dwellings)
with urine diversion and production of Aurin (nitrification - distillation)



How to transport further?

FreezePee project

A low(er)-tech concentration of urine
2024-2027



Funding agency



UNIVERSITÉ
PARIS-EST CRÉTEIL
VAL DE MARNE



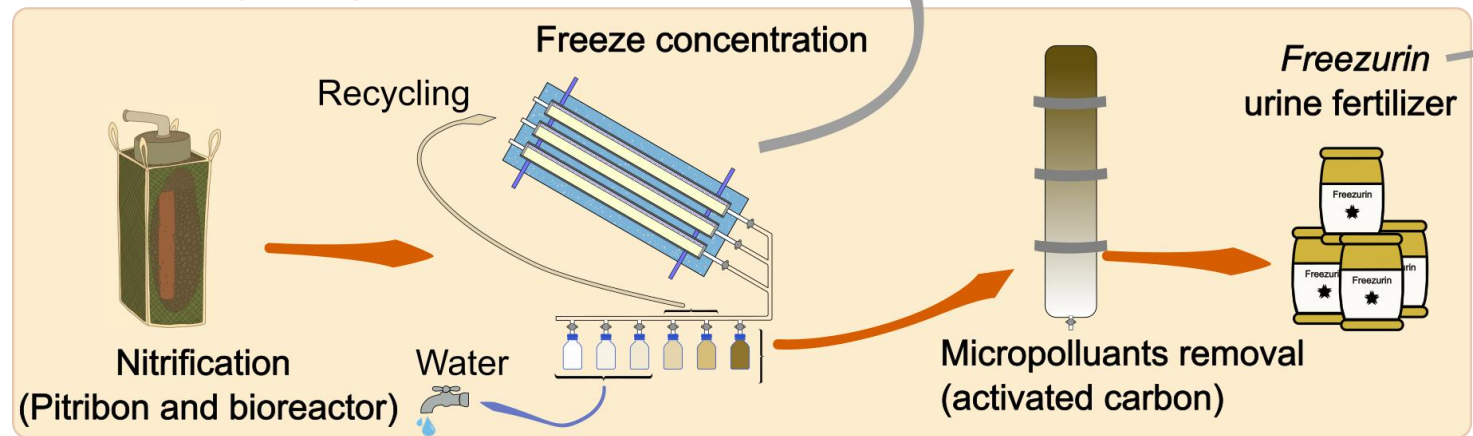
partners



Evaluation of **energy** consumption
by different freezing conditions

Analysis of Freezurin
(Nutrients and micropollutants)

Urine recycling and demonstrator



Noe-Hays et al., 2022. ACS EST Eng. 2, 446–455

<https://doi.org/10.1021/acsestengg.1c00271>

tools



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!