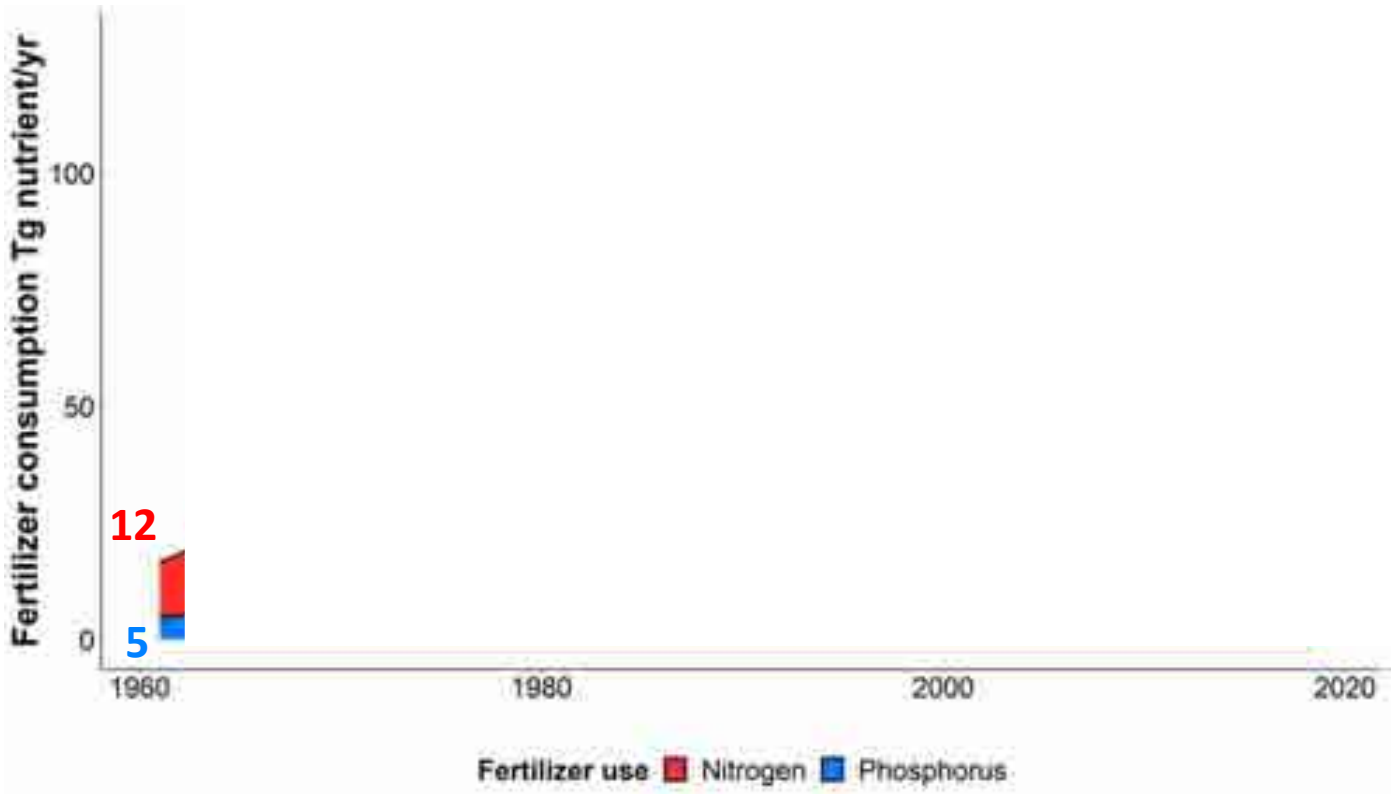
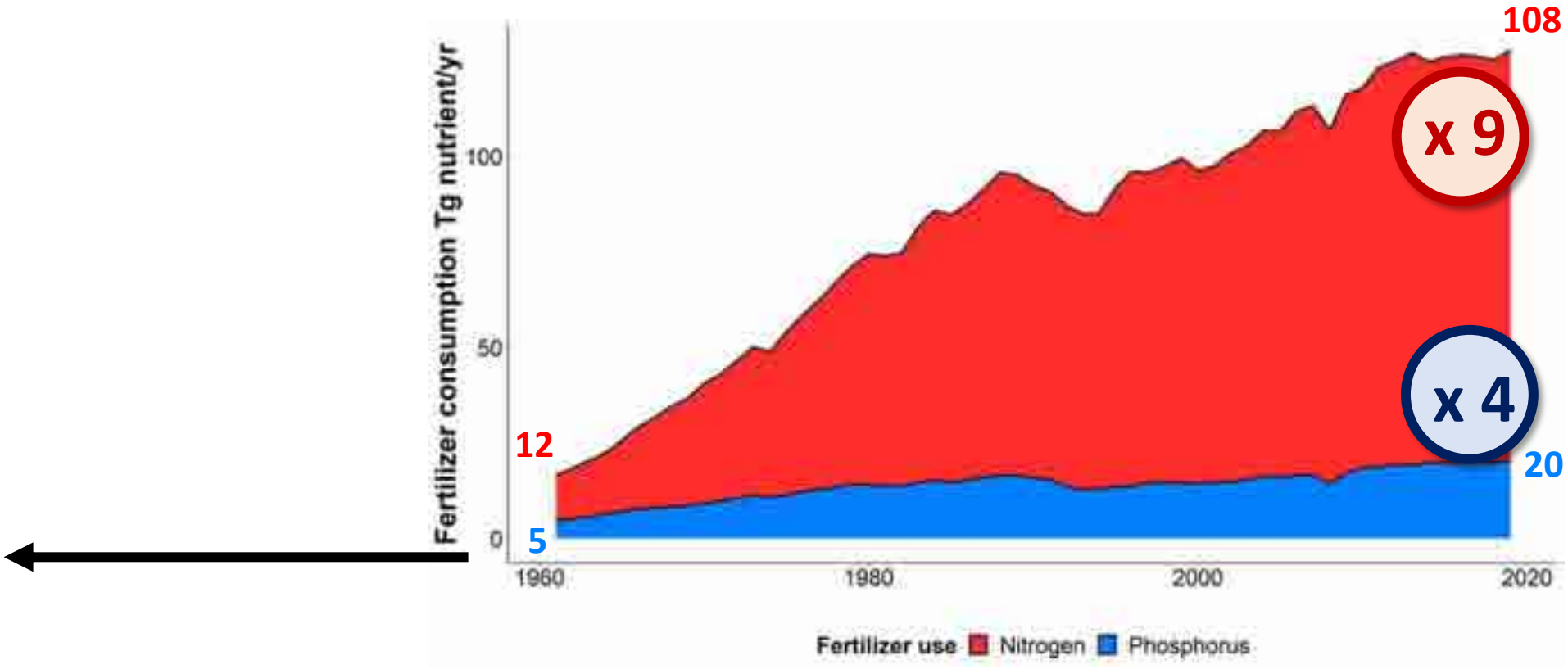
Past and future trends for N and P fertilization in the world

Luis Lassaletta

21-jun-22

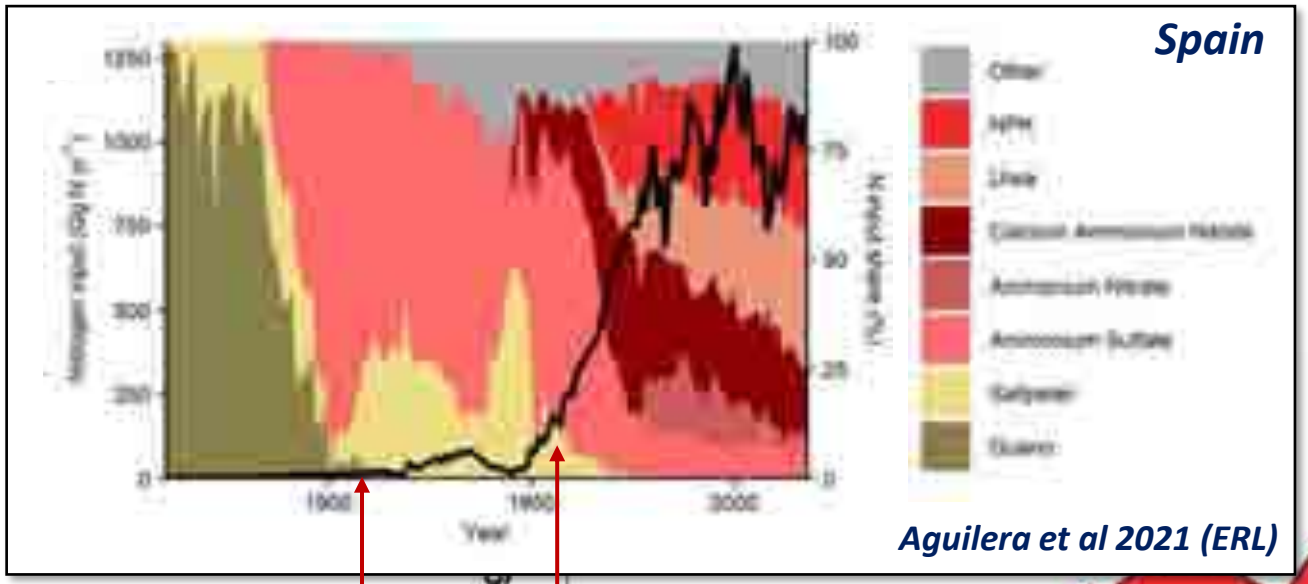


(Data source of the figure IFA 2022)



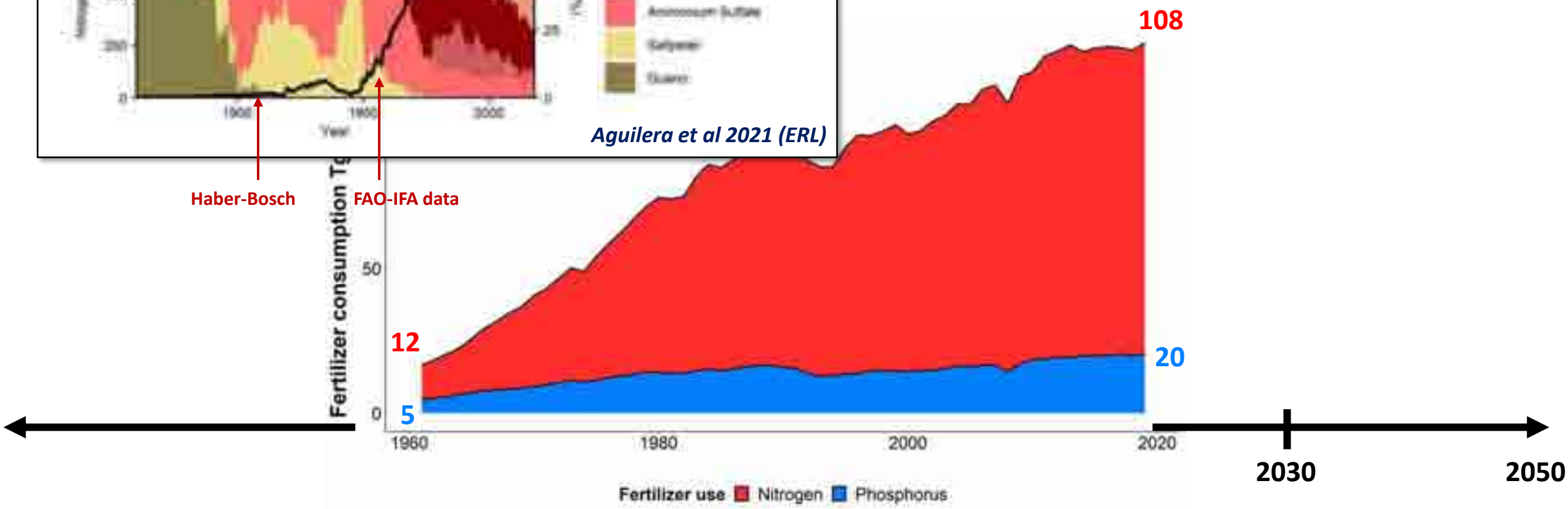
How was before 1961?

(Data source of the figure IFA 2022)



Haber-Bosch

FAO-IFA data



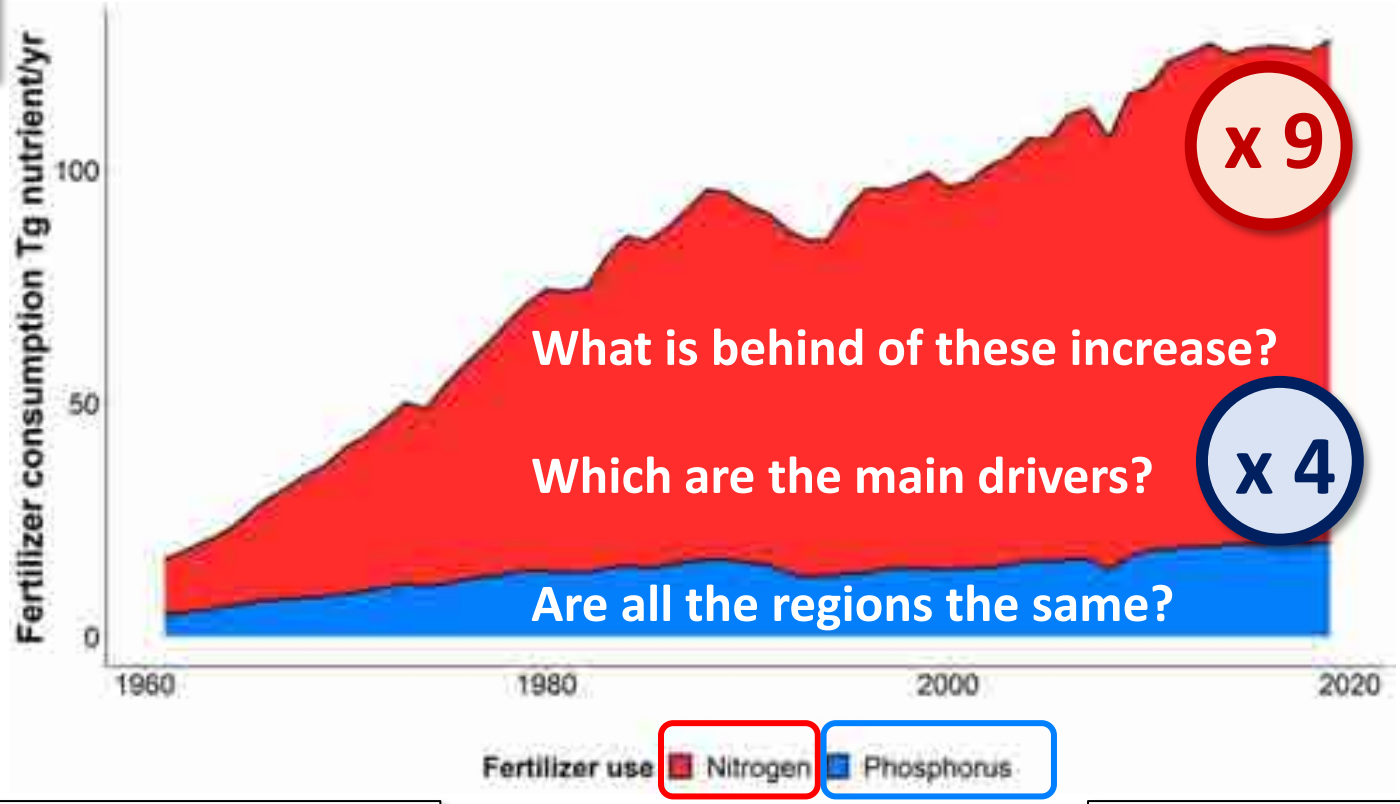
How was before 1961?

What about the future?

(Data source of the figure IFA 2022)

To imagine the future we first need to understand the past

1. Quality of the data?
2. The big picture



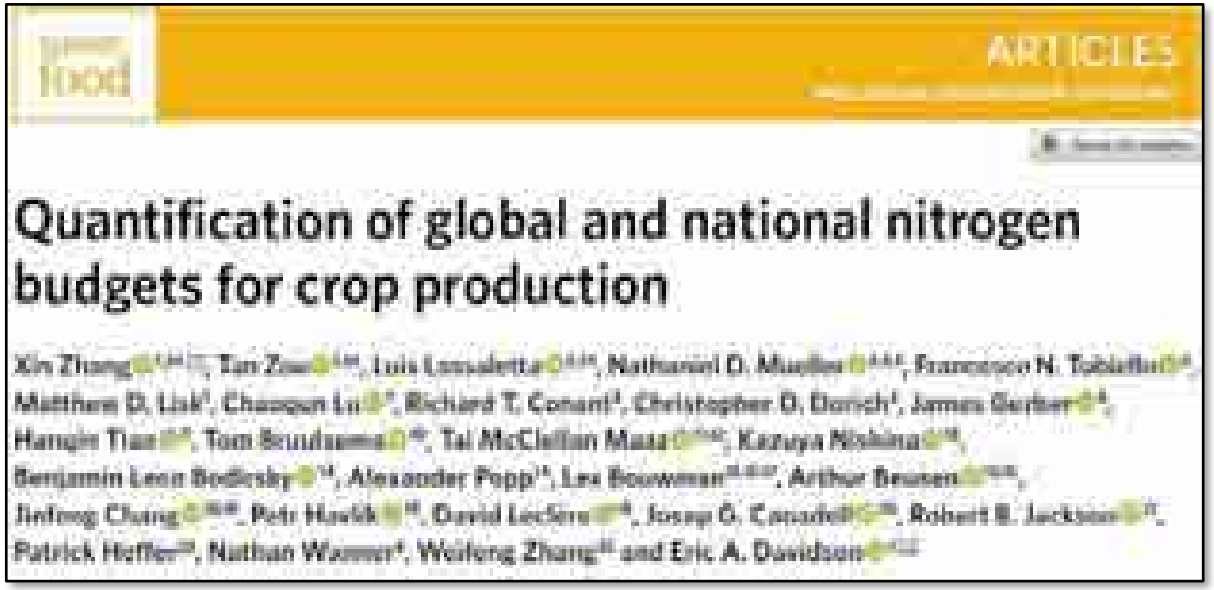
7. Future global scenarios

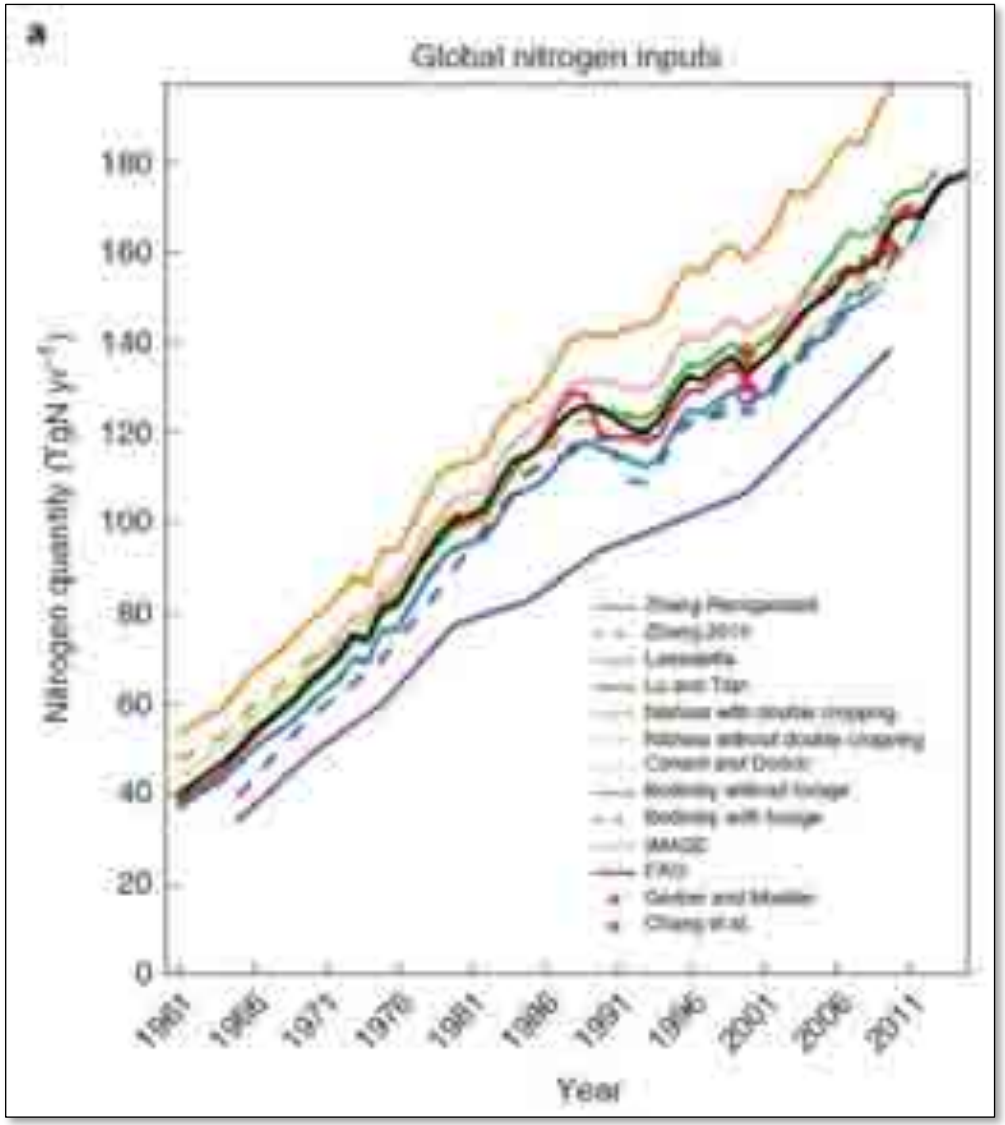
8. N_2O

3. Cropland expansion vs. intensification
4. Other inputs

5. Efficiencies
6. Rotations, nutrient legacies and crop-mix

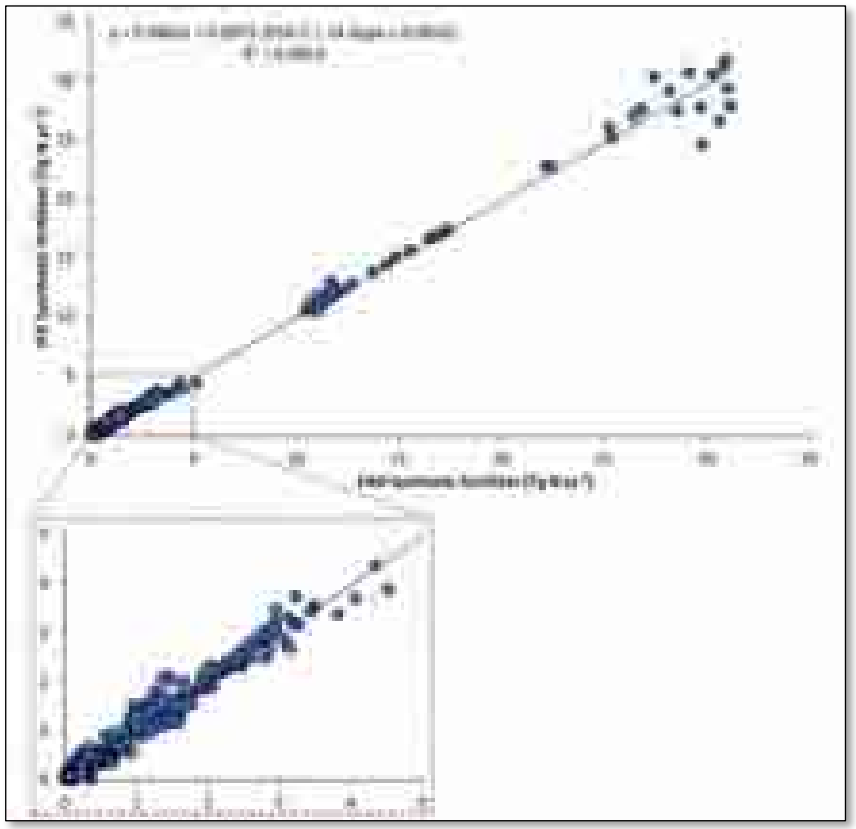
1. The quality of the data





Global datasets comparison

Global Nutrient Budget Platform



Global Symposium on Soils for Nutrition, FAO Virtual Event, 26/07/2022 - 29/07/2022, https://www.fao.org/events/detail/symposium-soils-for-nutrition/en

Towards a global nutrient budget data platform

A. DOBERMANN, International Fertilizer Association; R. EINARSSON, Universidad Politécnica de Madrid; P. GRASSINI, University of Nebraska-Lincoln; A. GRUERE, International Fertilizer Association; L. LASSALETTA, Universidad Politécnica de Madrid; C. LUDEMANN, Wageningen UR; F. TUBIELLO, FAO; M. VAN ITTERSUM, Wageningen UR; N. WANNER, FAO; X. ZHANG, University of Maryland Center for Environmental Science

IFA vs FAO
Today: important coordination and harmonization

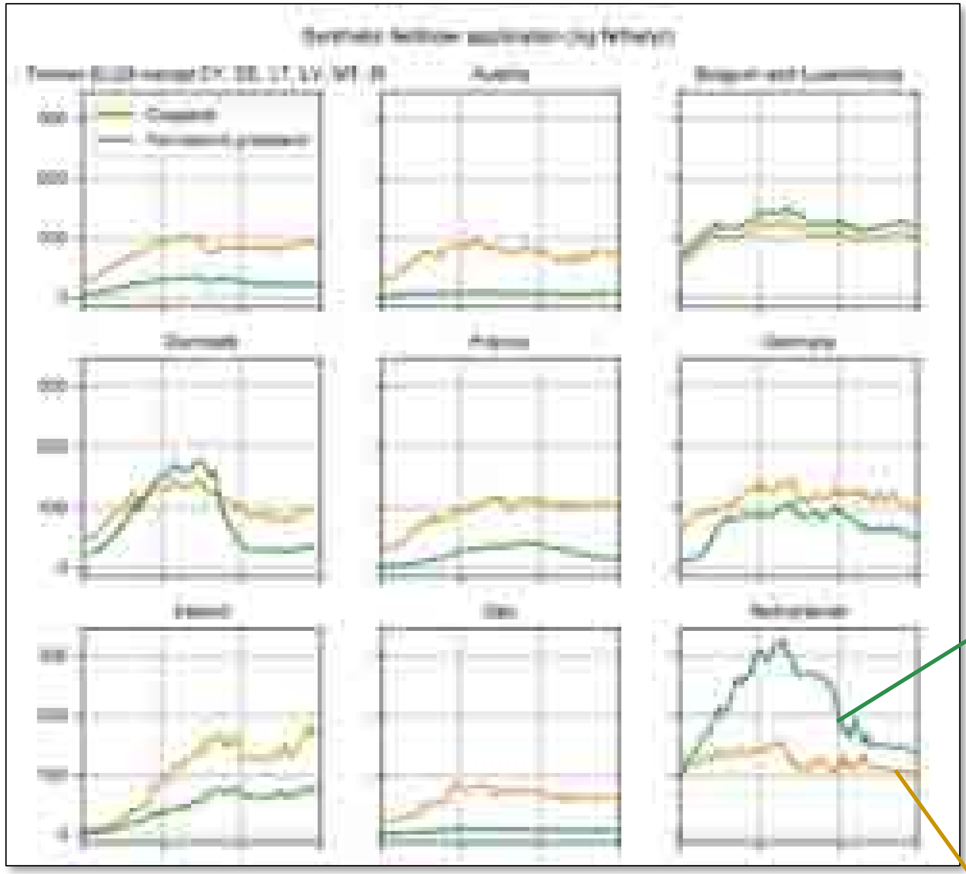
1. The quality of the data

scientific **data**

OPEN

DATA DESCRIPTOR

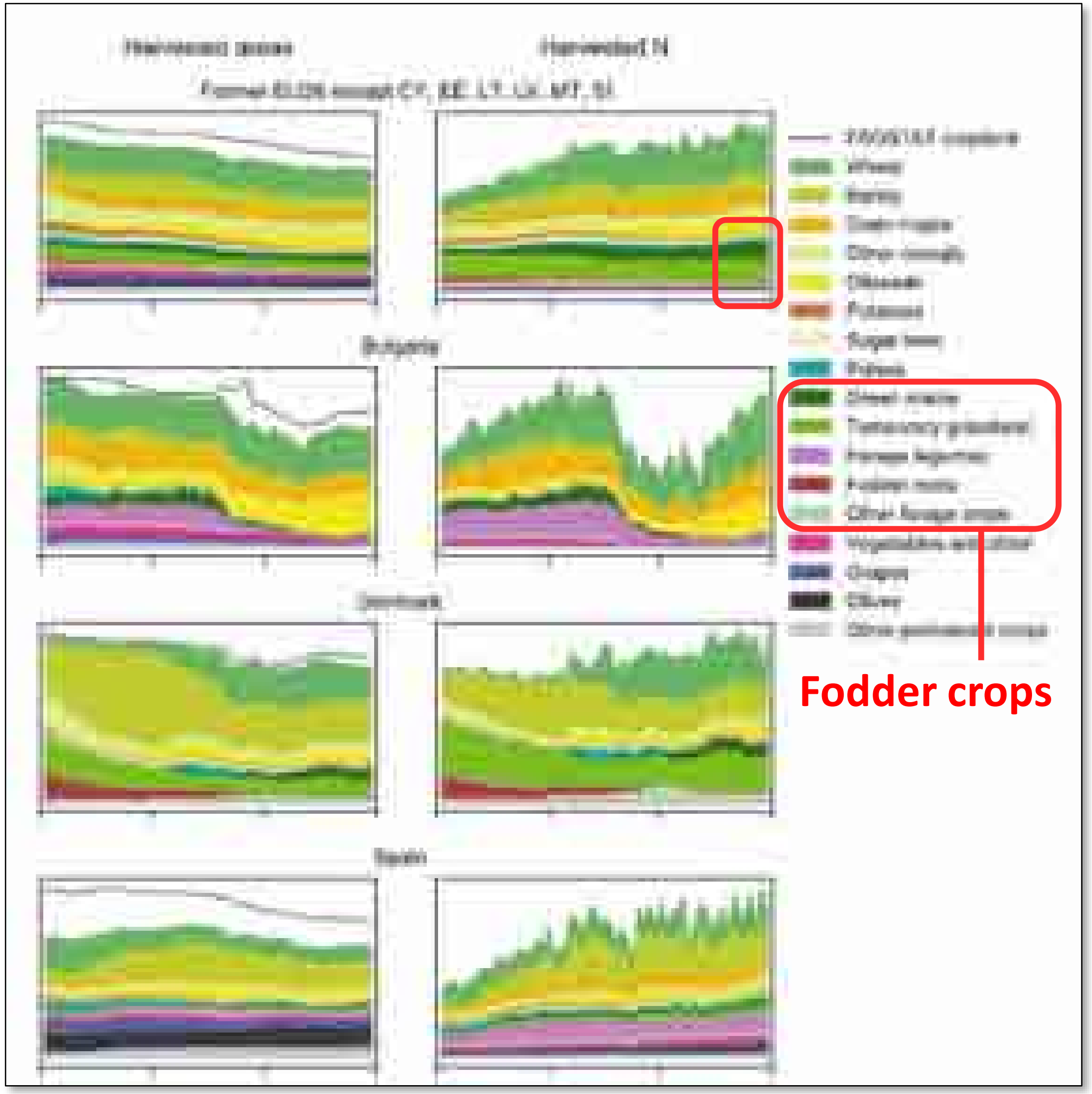
Crop production and nitrogen use in European cropland and grassland 1961–2019



Fertilized permanent grasslands

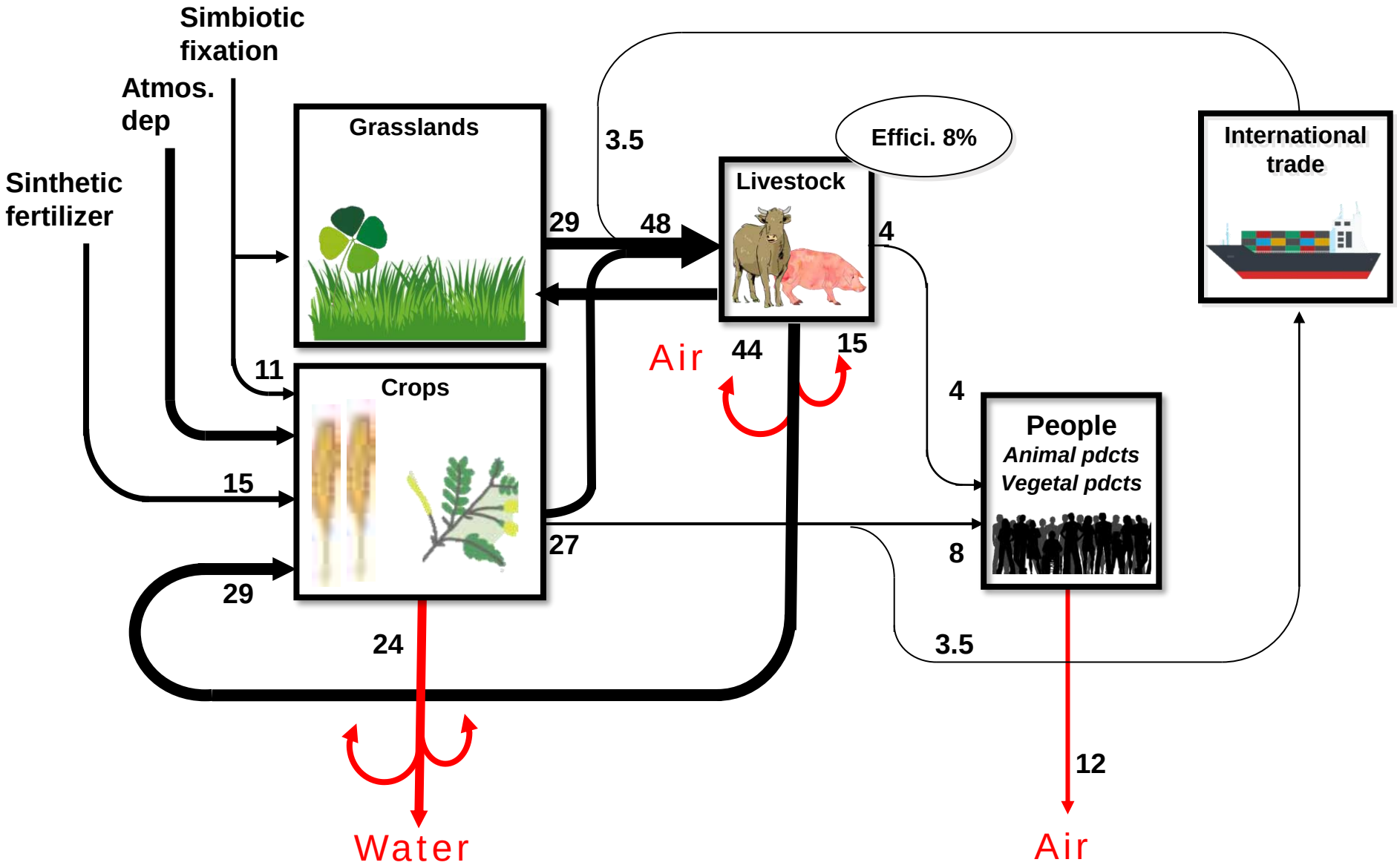
Grassland

Crop



Fodder crops

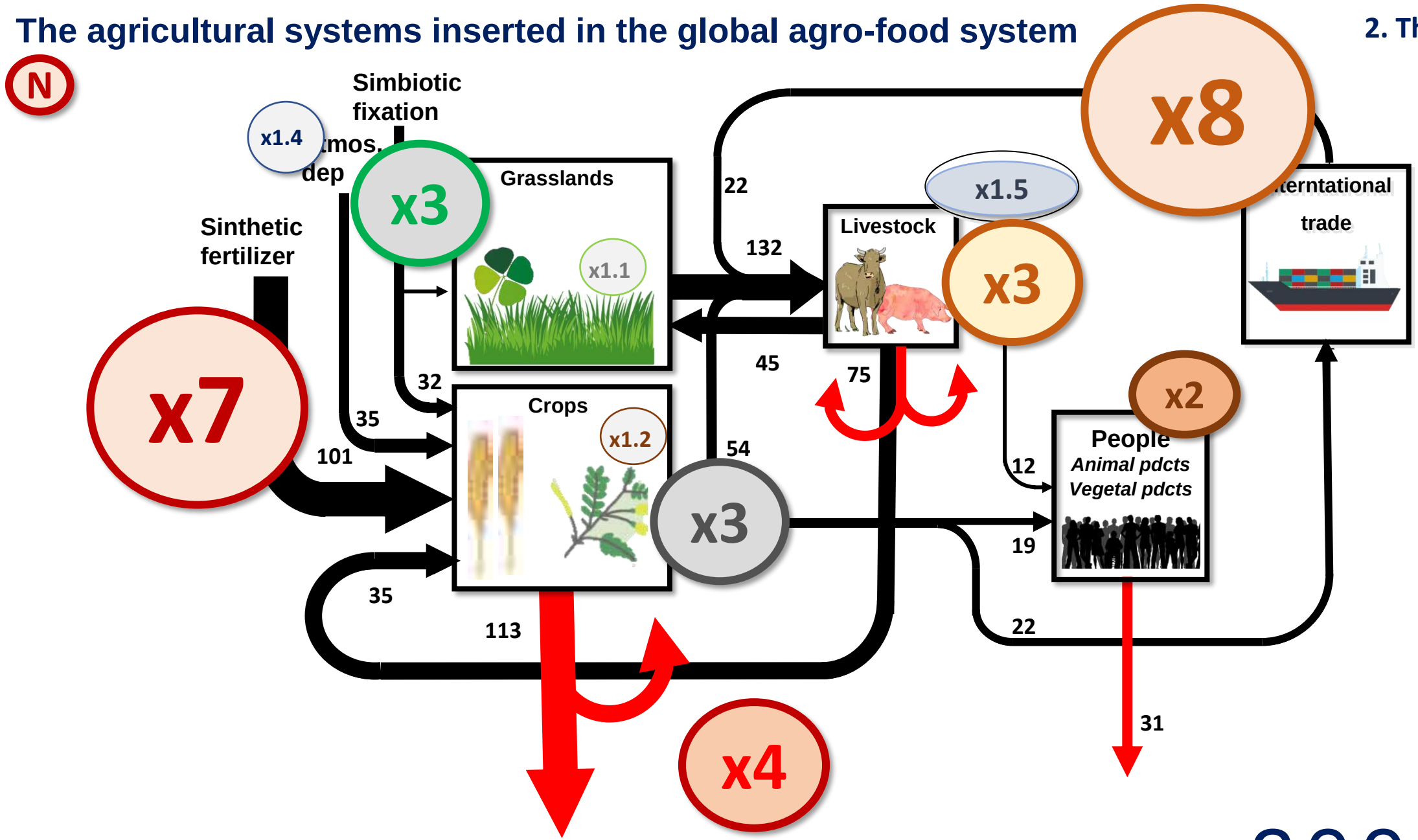
The agricultural systems inserted in the global agro-food system



Billen, et al. 2014 (Global Food Security): The GRAFS approach
Lassaletta et al. 2016 (Env. Res Lett.)

1961-65

The agricultural systems inserted in the global agro-food system



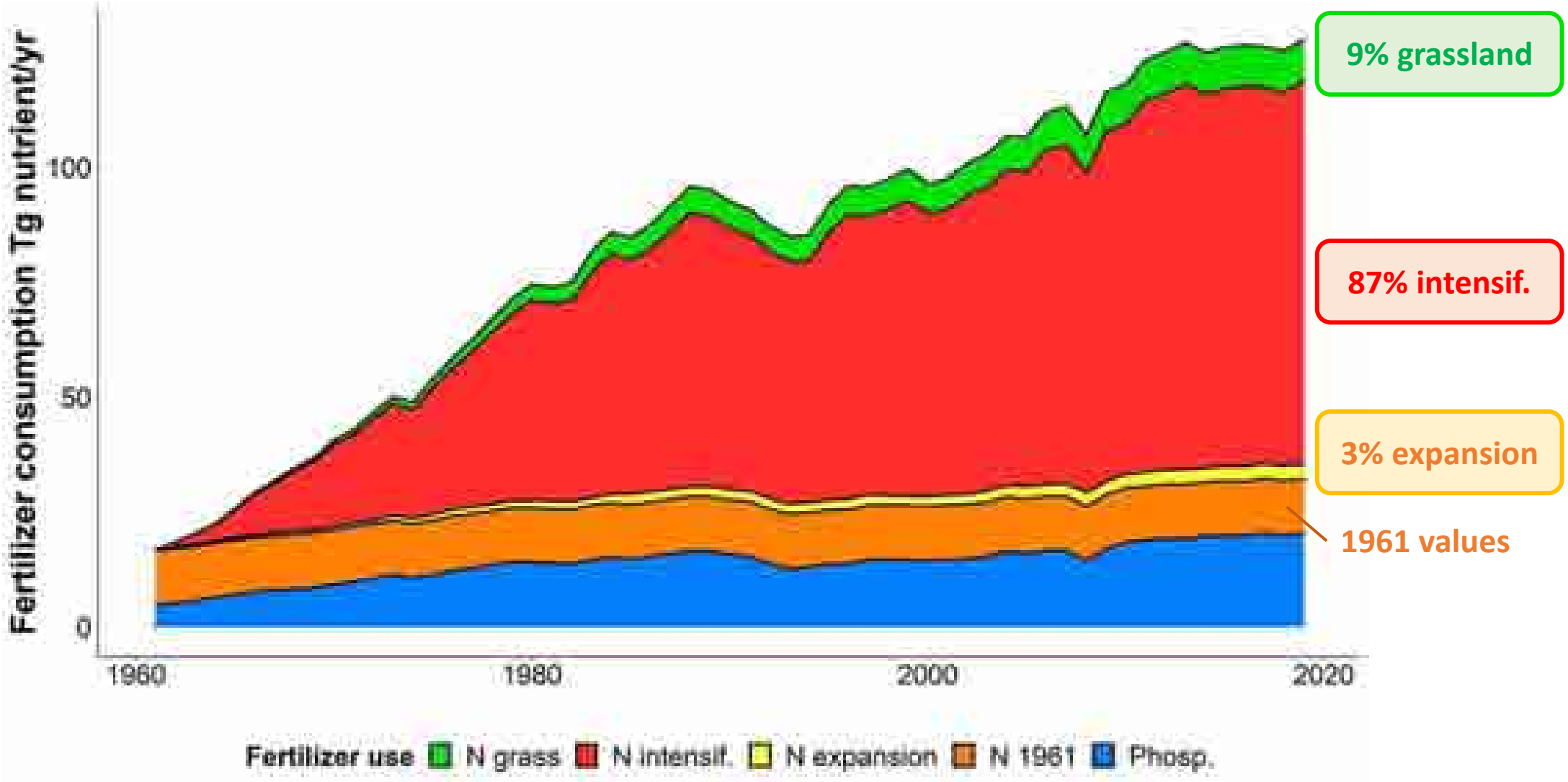
2005-09

Billen, et al. 2014 (Global Food Security): The GRAFS approach
Lassaletta et al. 2016 (Env. Res Lett.)

3. Land increase vs. intensification

N

P



9% grassland

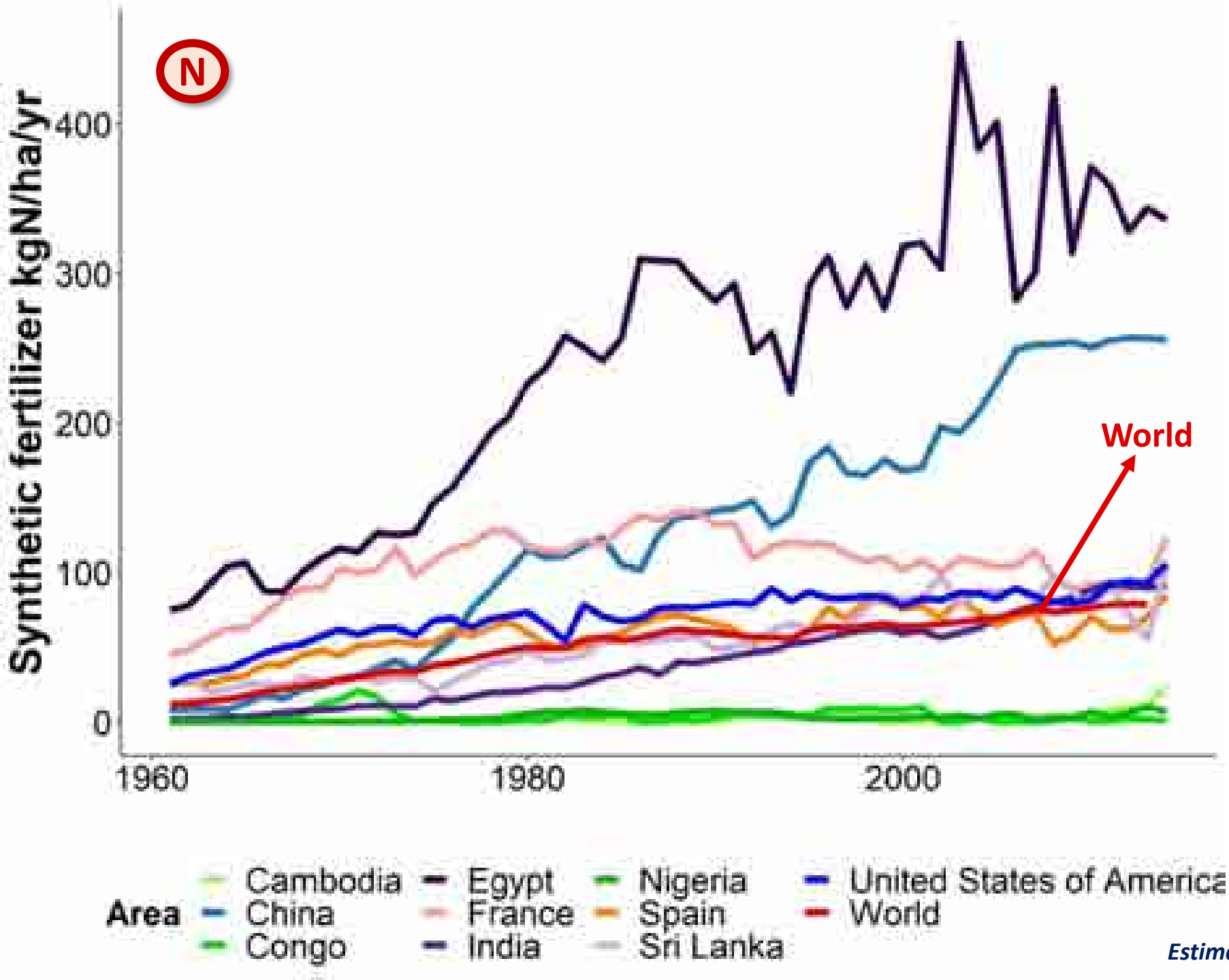
87% intensif.

3% expansion

1961 values

Estimated from Lassaletta et al. 2016 (Env. Res Lett.)

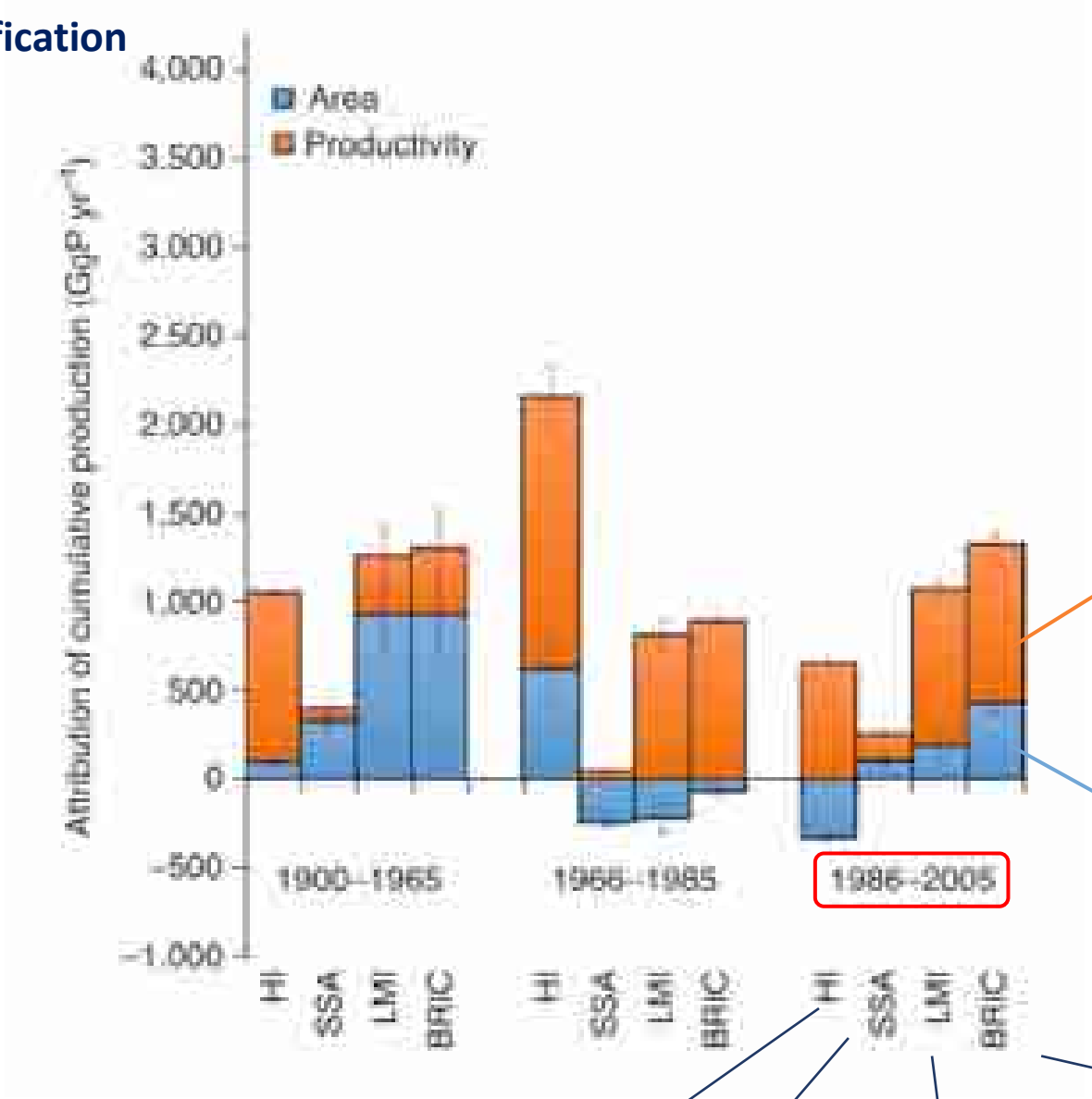
3. Land increase vs. intensification



Strong diversity!

Estimated from Lassaletta et al. 2016 (Env. Res Lett.)

3. Land increase vs. intensification



Most of the increase in production is associated to productivity increases

Increase due to higher productivities

Increase due to cropland expansion

High income

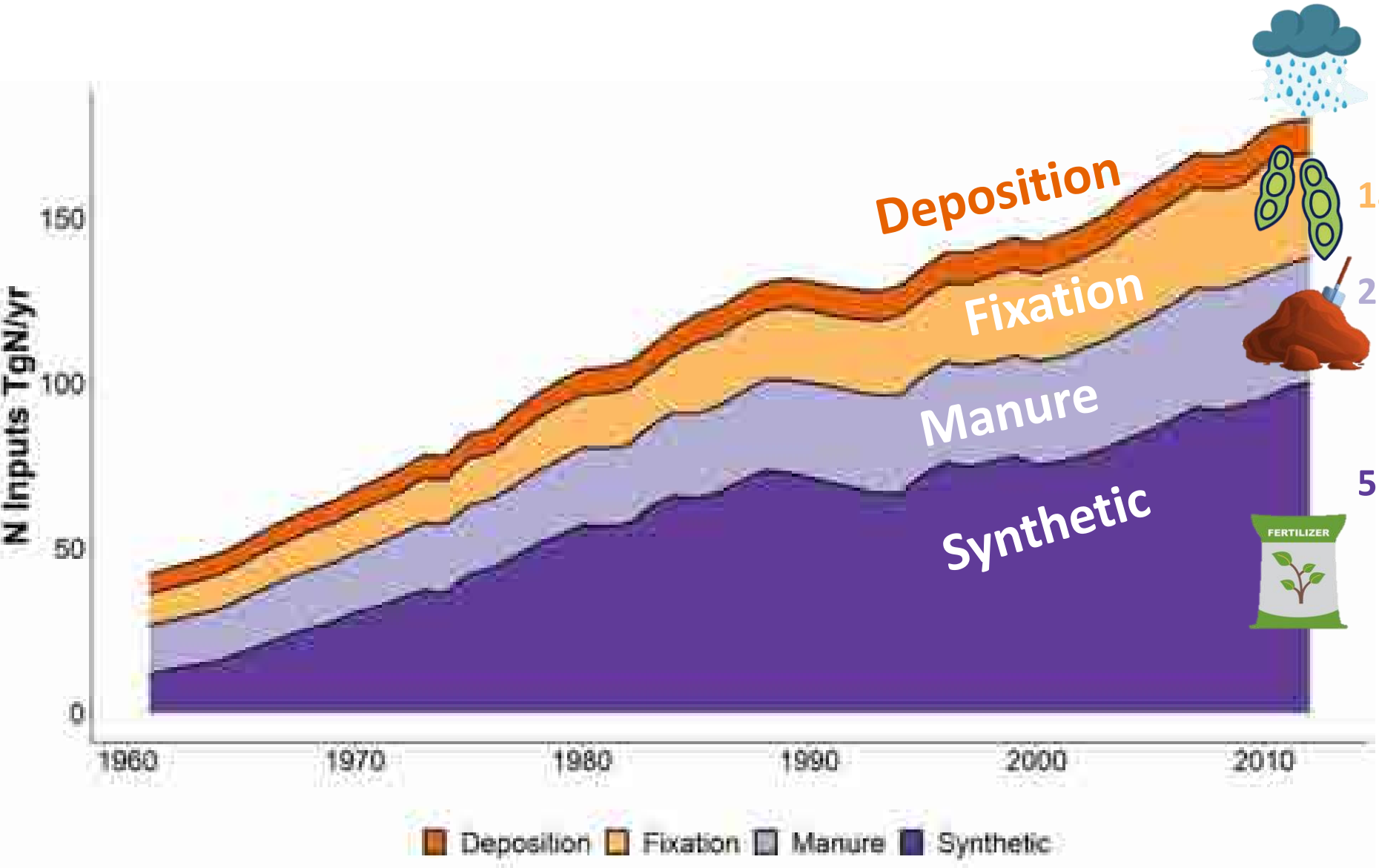
Sub-Saharan

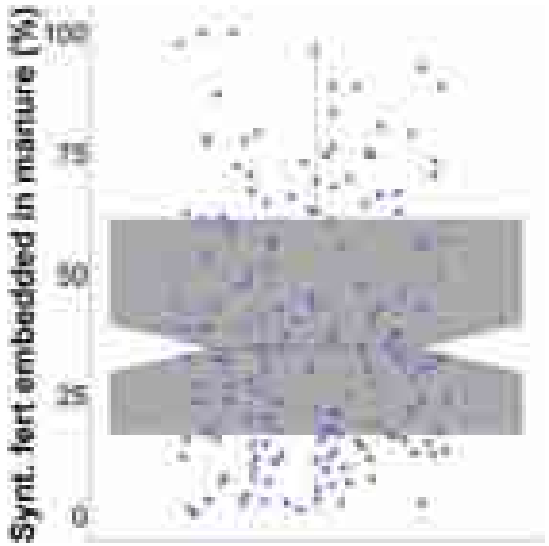
Low-middle income

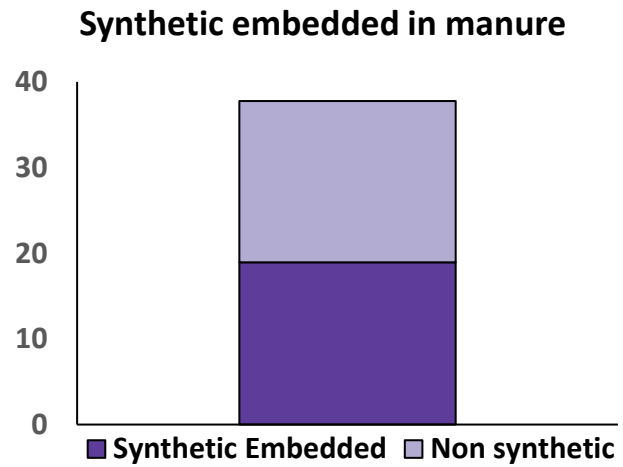
Brazil, Russia, India China

Mogollón et a. 2021 (Nature Food)

4. Other inputs







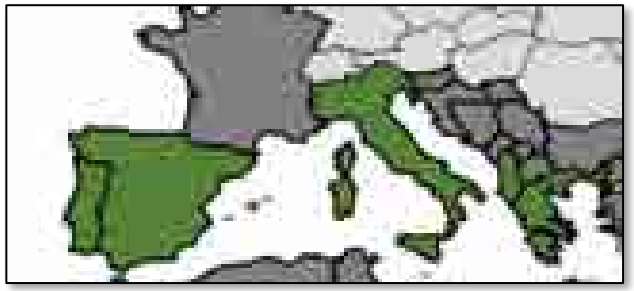
Estimated from Lassaletta et al. 2016 (Env. Res Lett.)

Lassaletta et al. (in prep.)

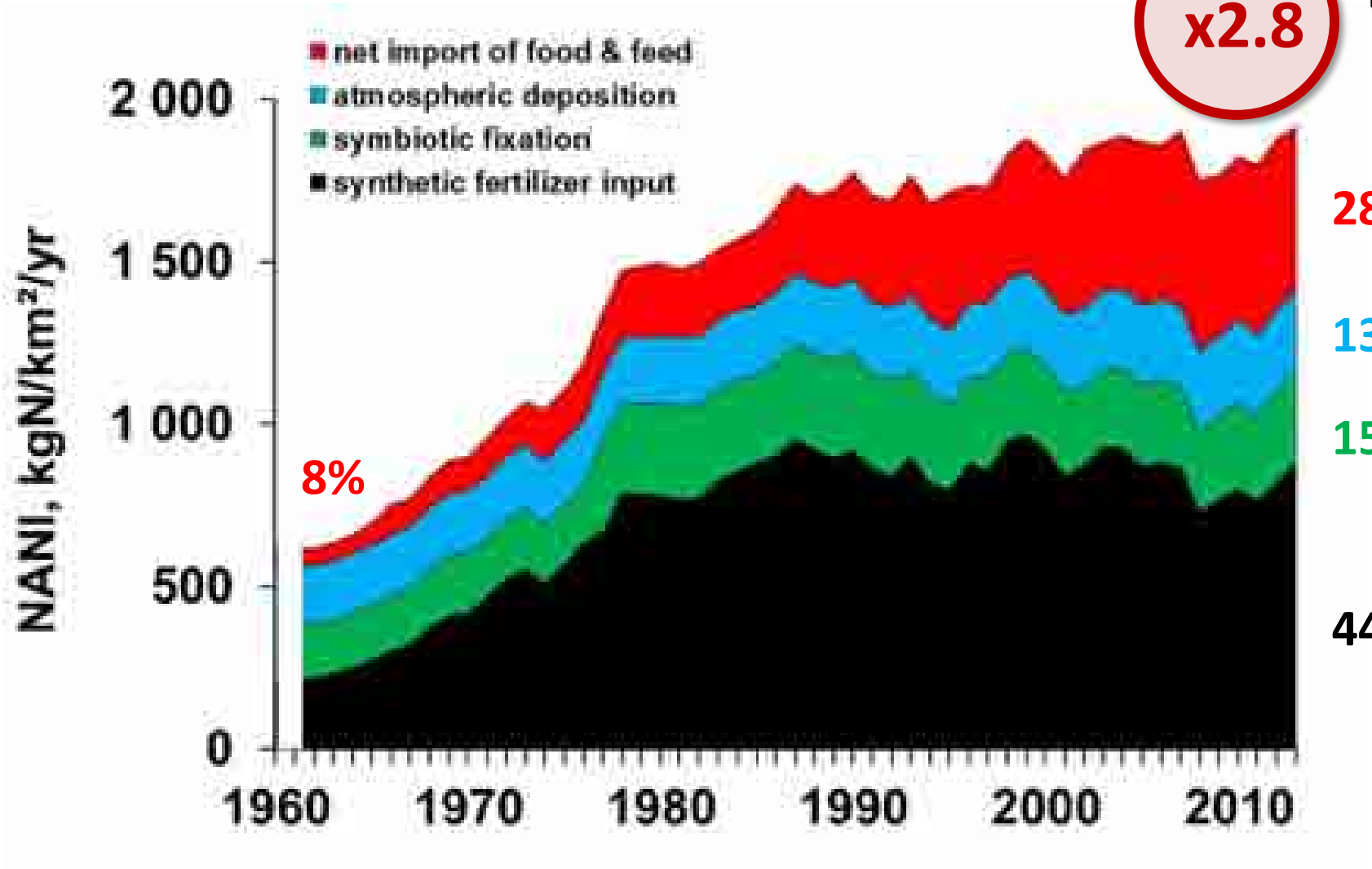
4. Other inputs

N

Total inputs to a region

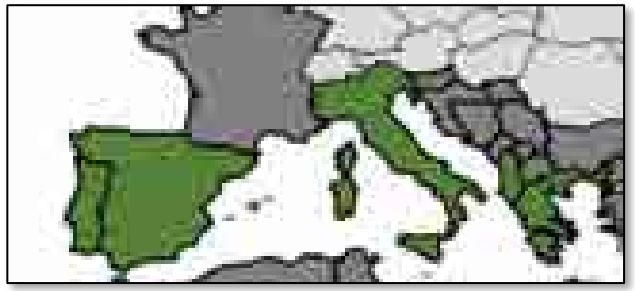


The Mediterranean Region

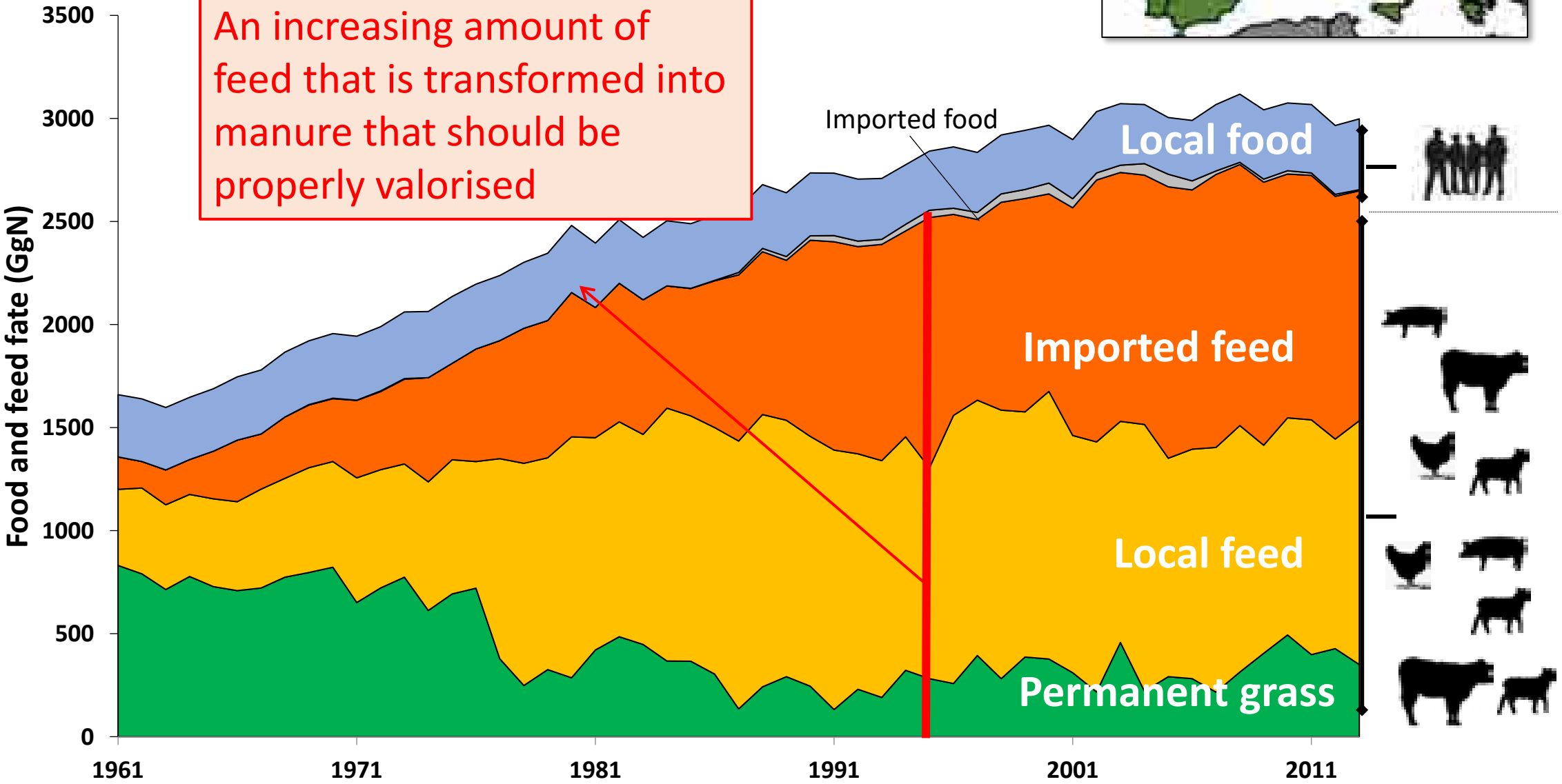


Lassaletta et a. 2021 Env. Res Lett.

North Mediterranean

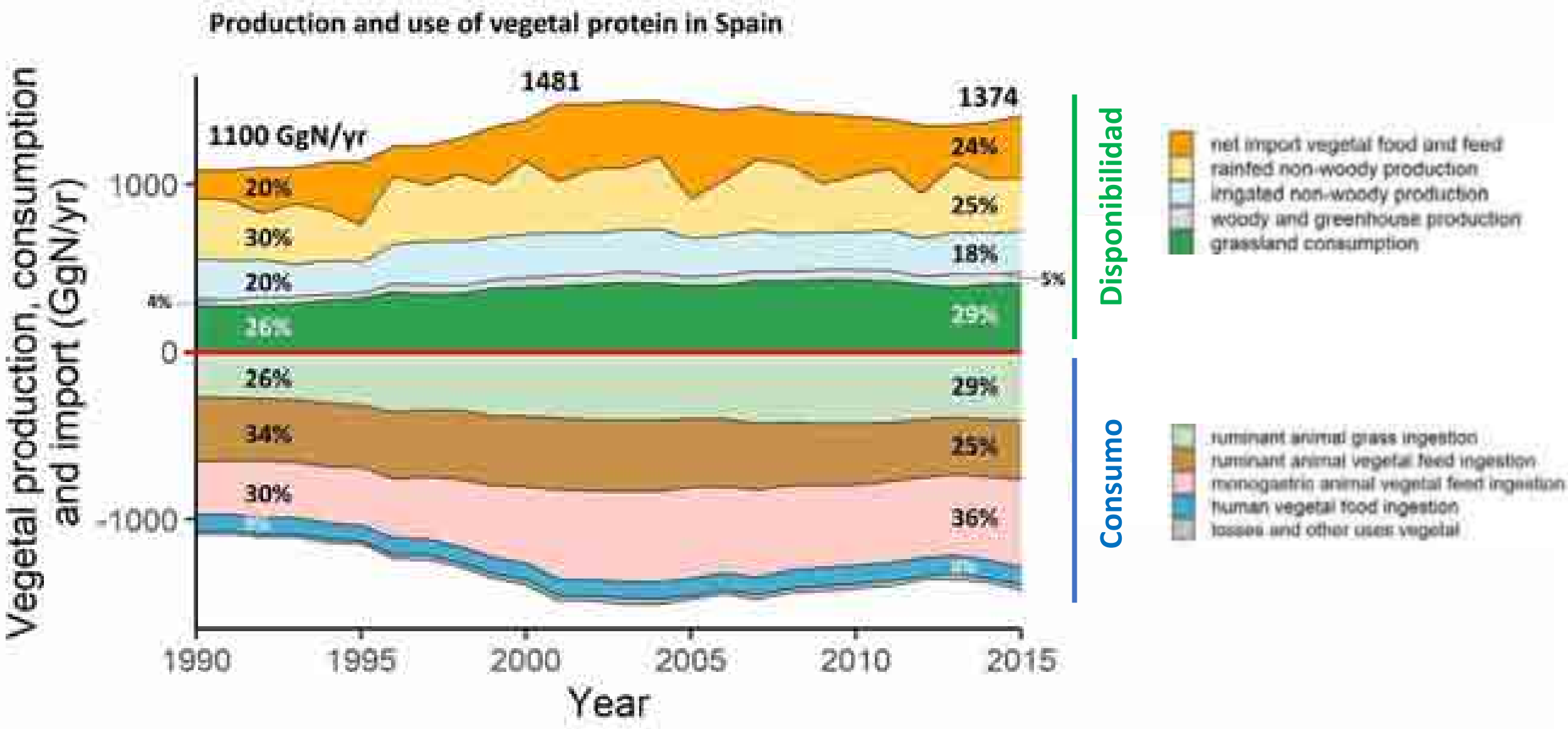


An increasing amount of feed that is transformed into manure that should be properly valorised



Lassaletta et a. 2021 (Env. Res Lett.)

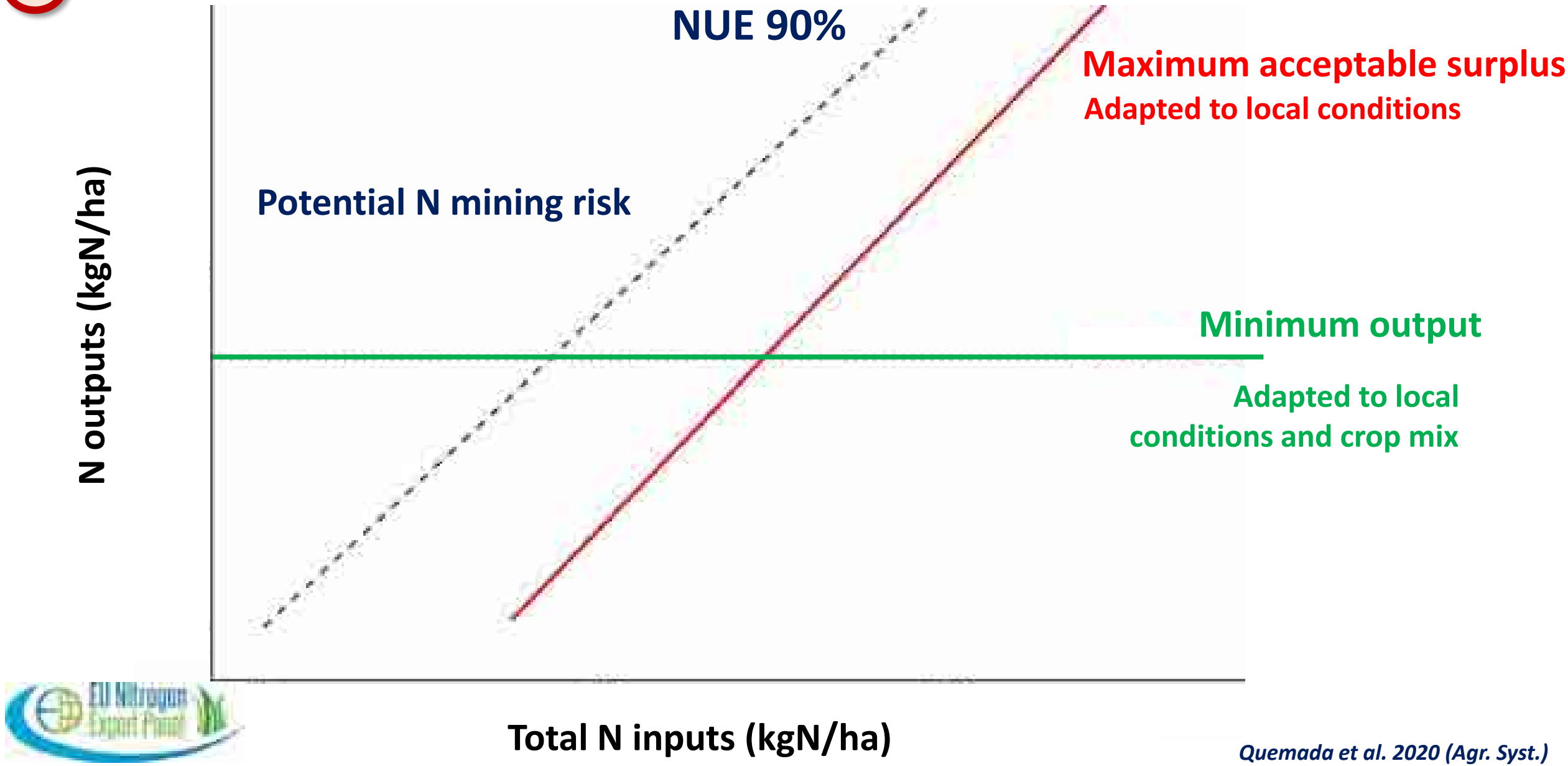
Spain



Rodriguez et a. 2021 (In prep)

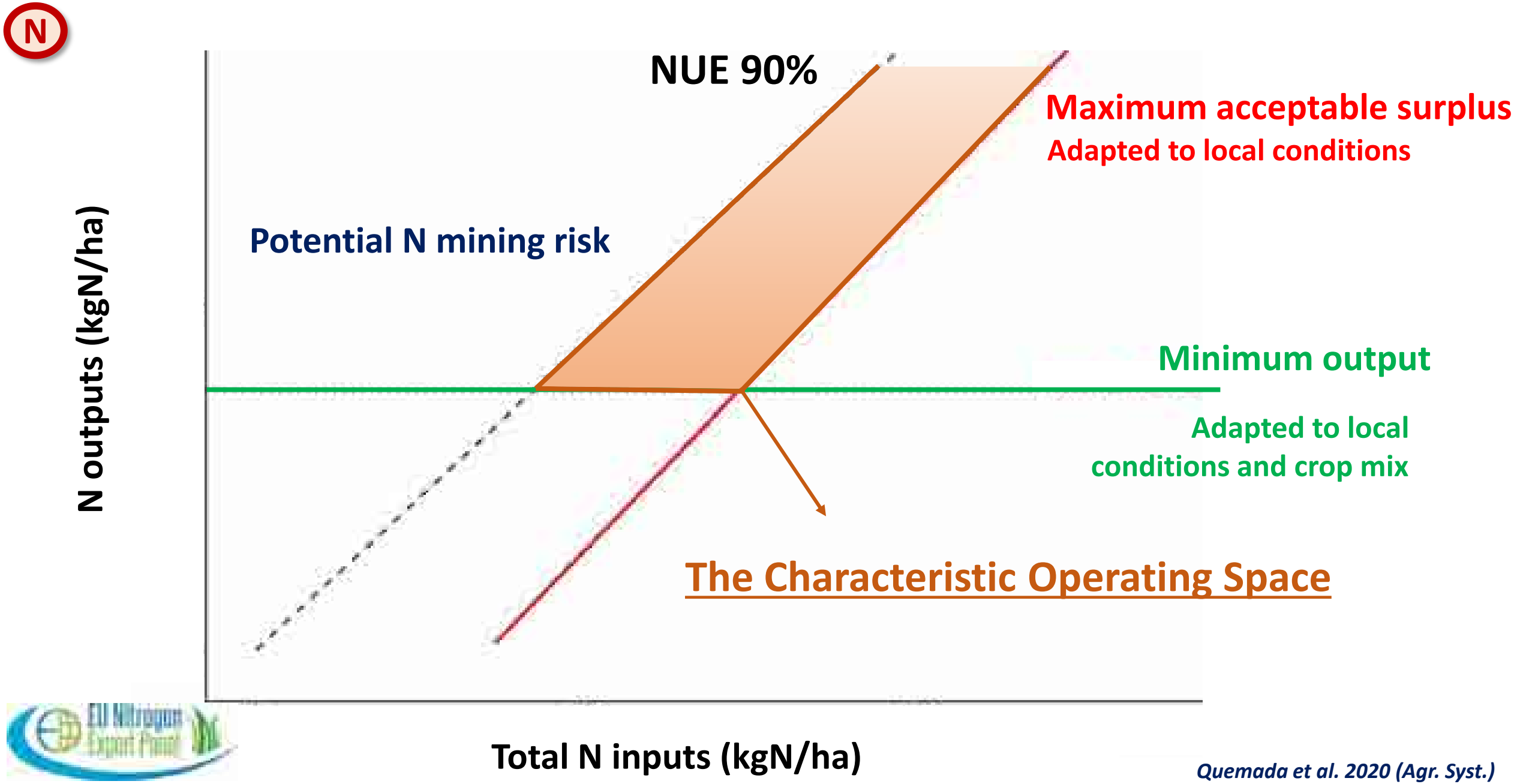
5. Efficiencies: Contrasting trends

Easy-to-use indicator for ‘nitrogen use efficiency’ (EUNEP)



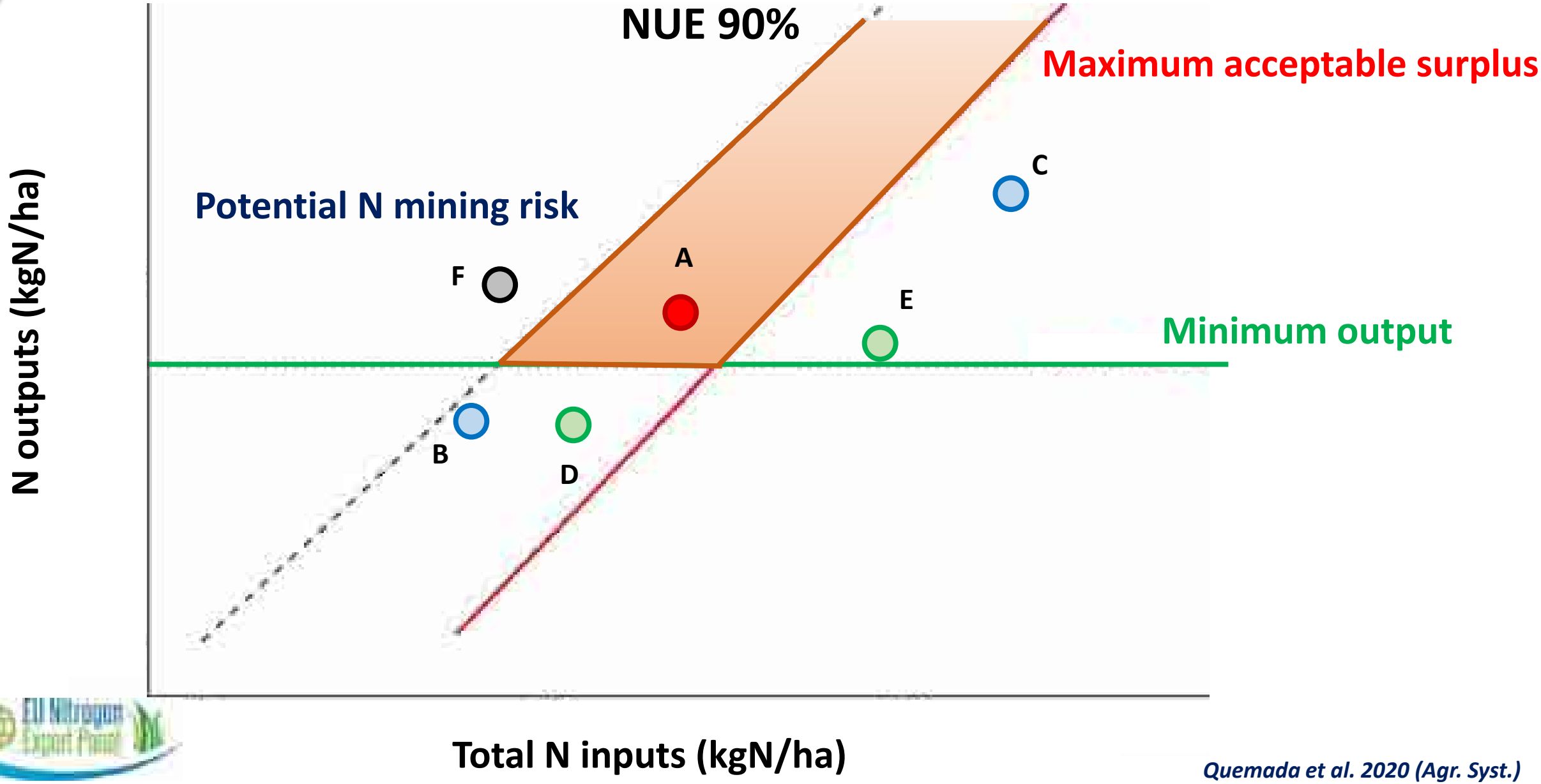
Quemada et al. 2020 (Agr. Syst.)

Easy-to-use indicator for 'nitrogen use efficiency' (EUNEP)



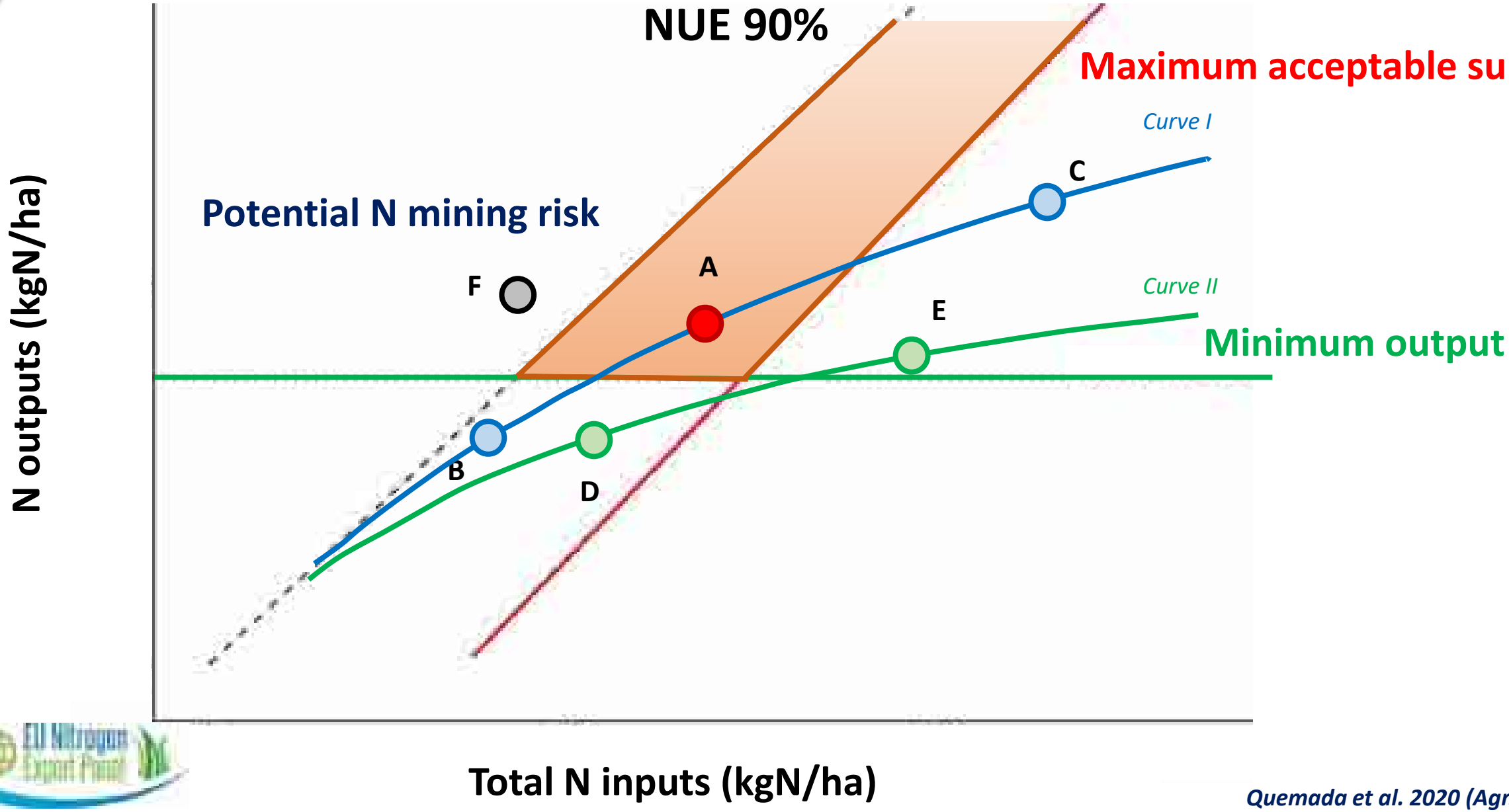
Quemada et al. 2020 (Agr. Syst.)

The Transition Pathways



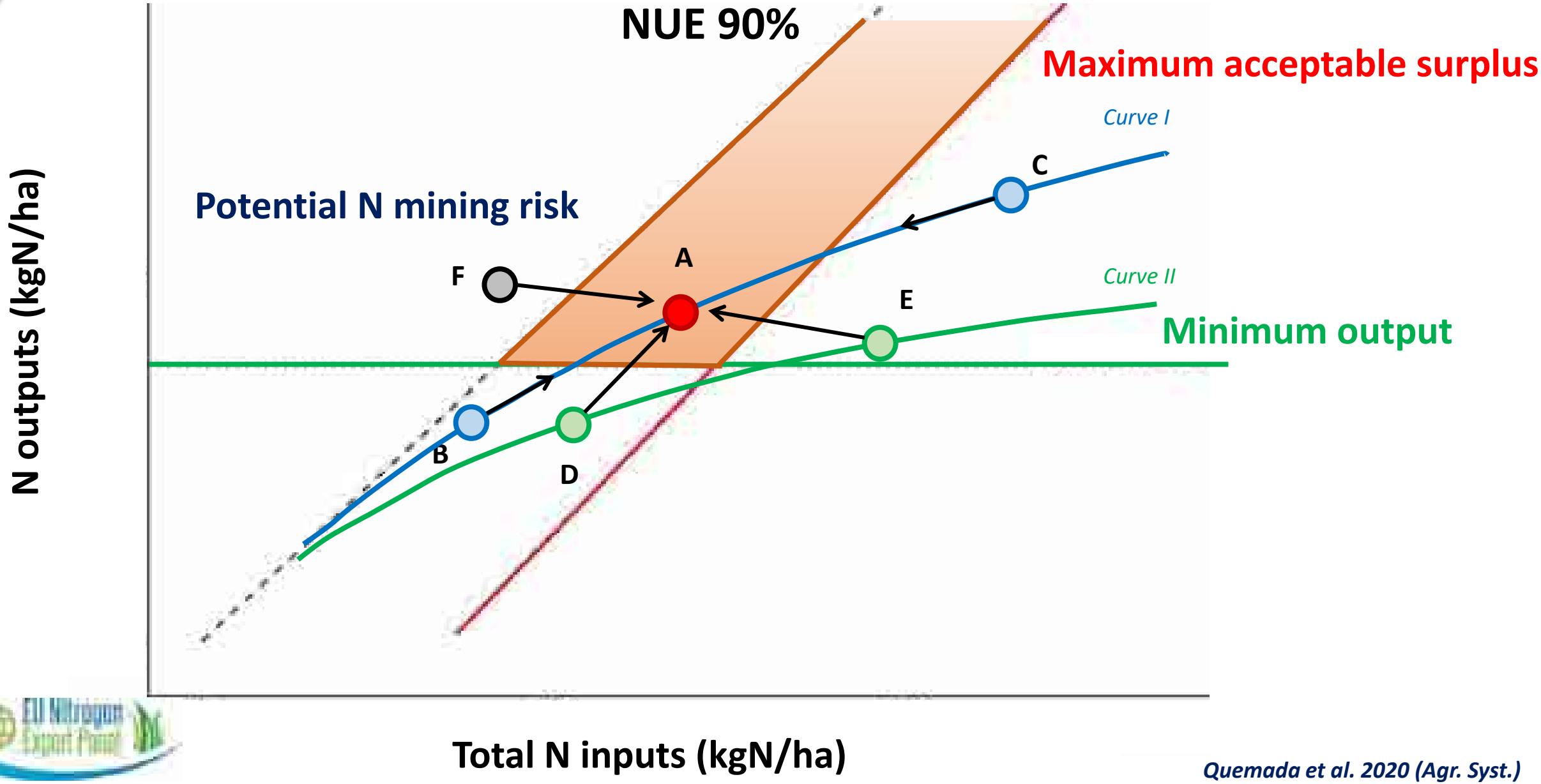
Quemada et al. 2020 (Agr. Syst.)

The transition pathways



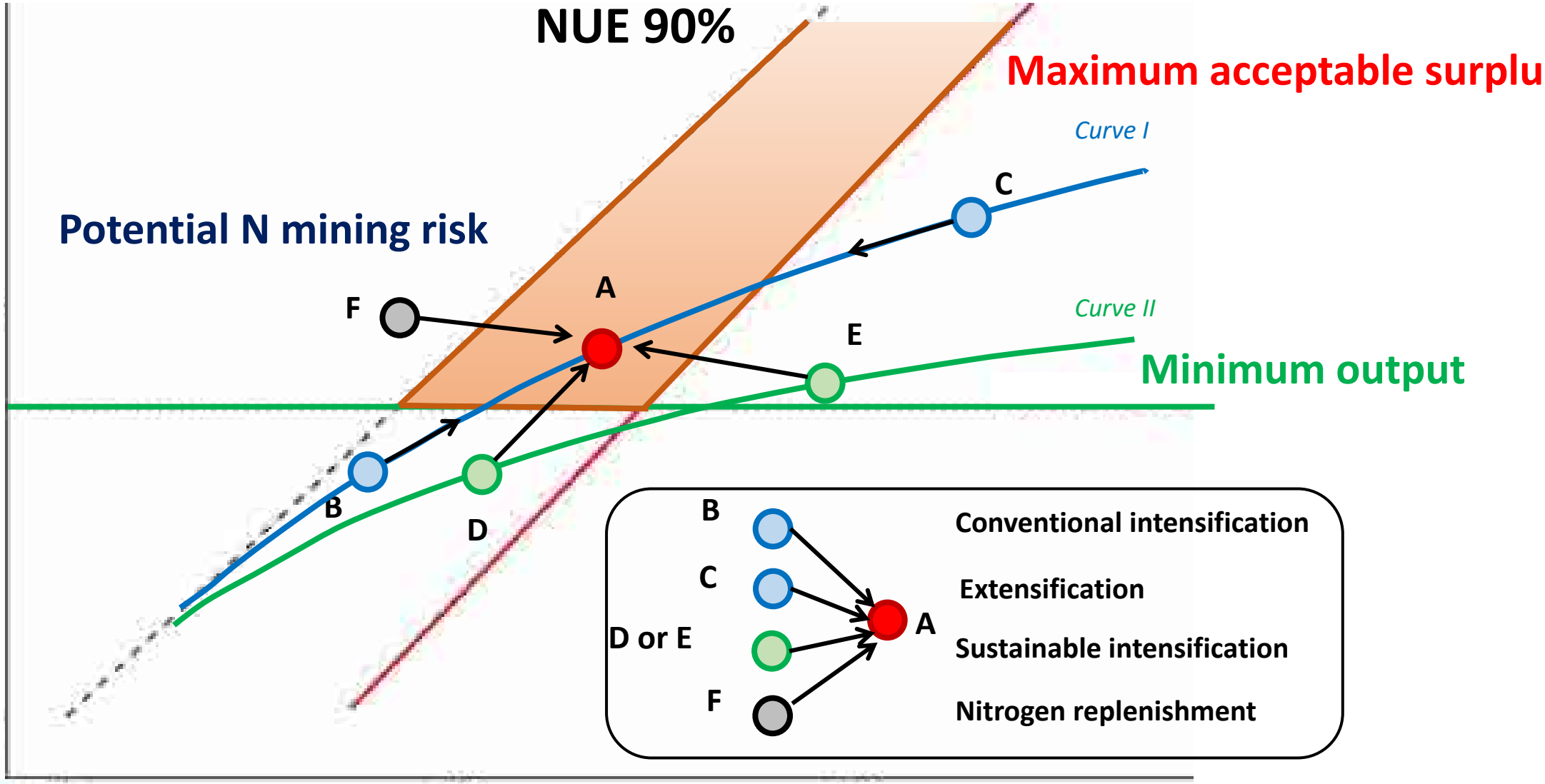
Quemada et al. 2020 (Agr. Syst.)

The transition pathways



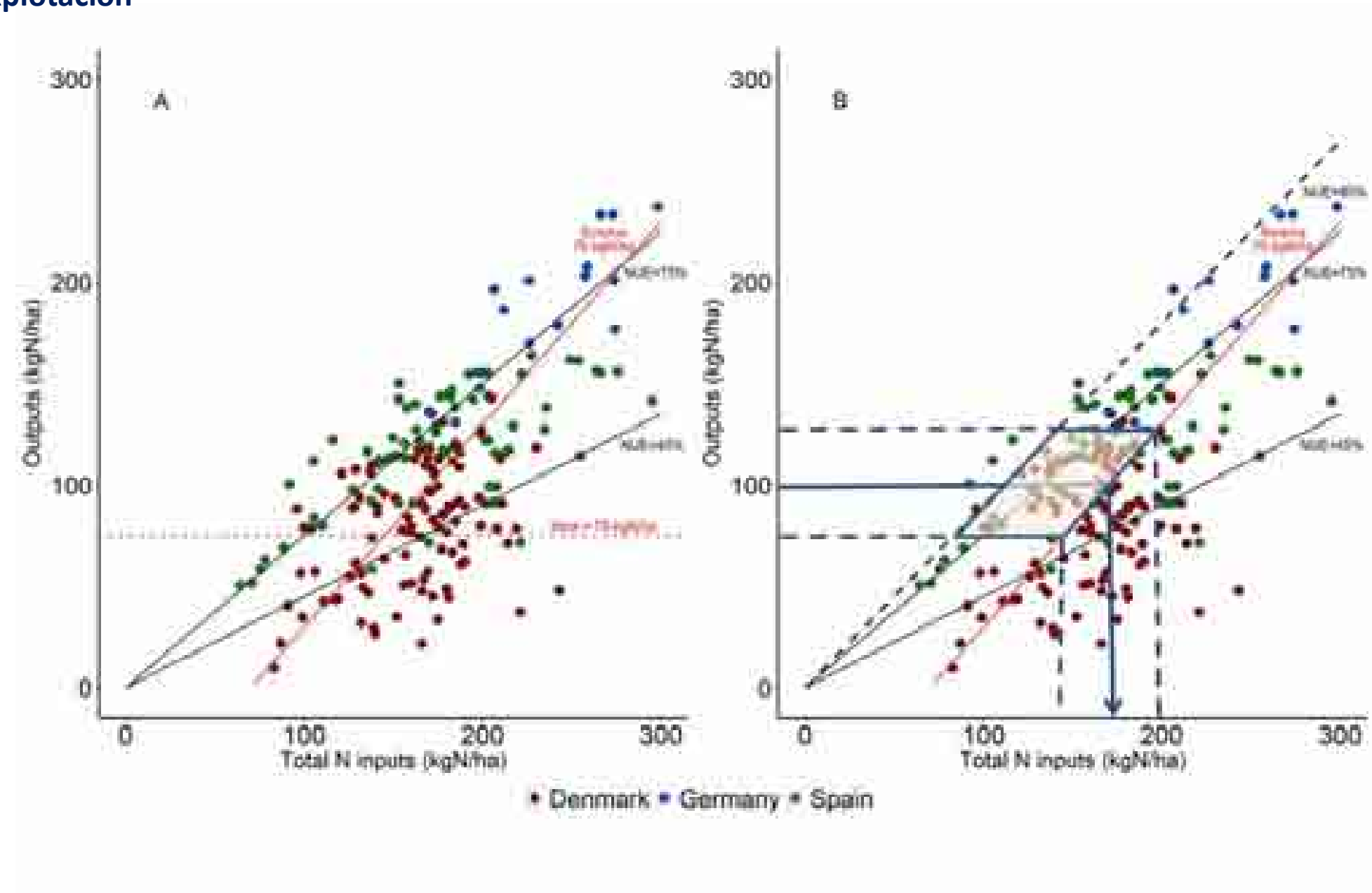
Quemada et al. 2020 (Agr. Syst.)

The transition pathways



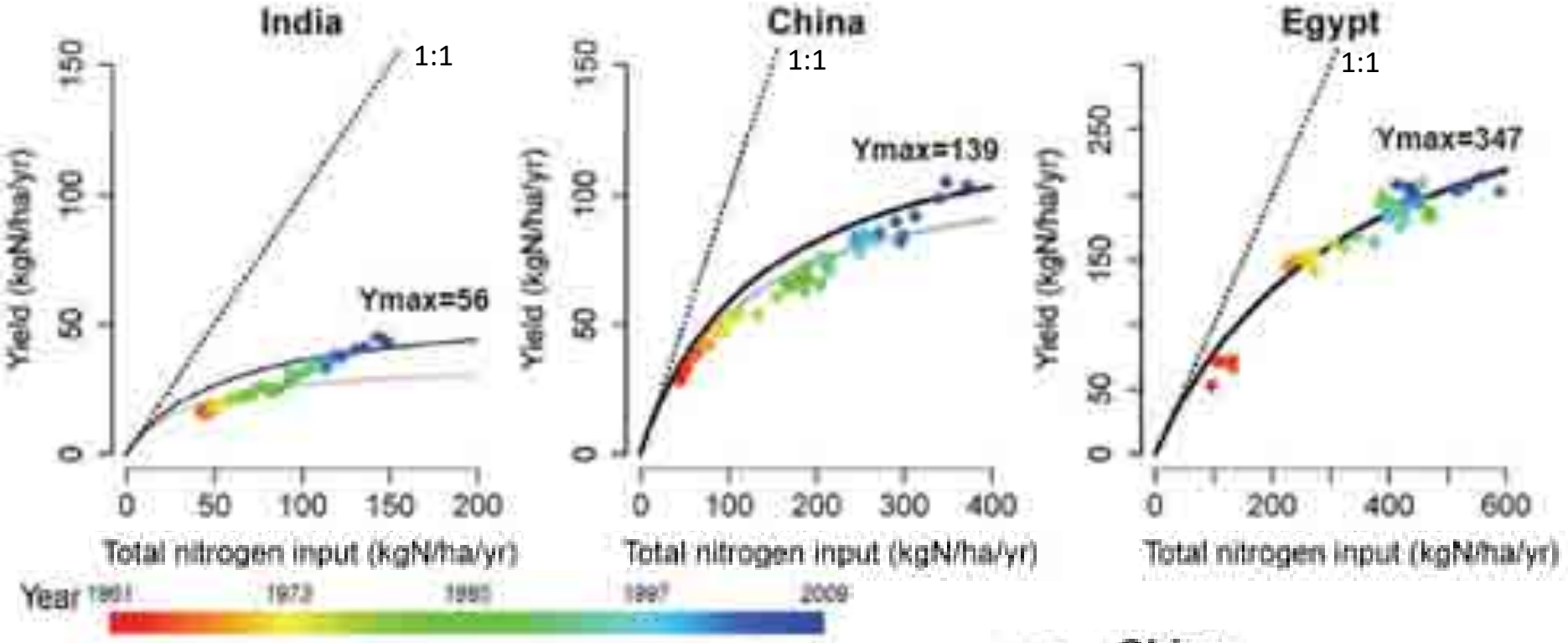
Quemada et al. 2020 (Agr. Syst.)

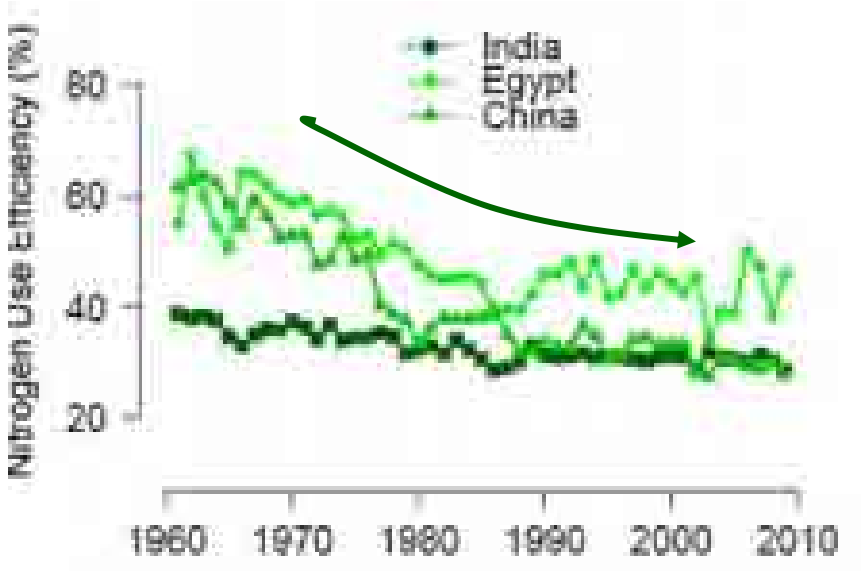
Escala de explotación

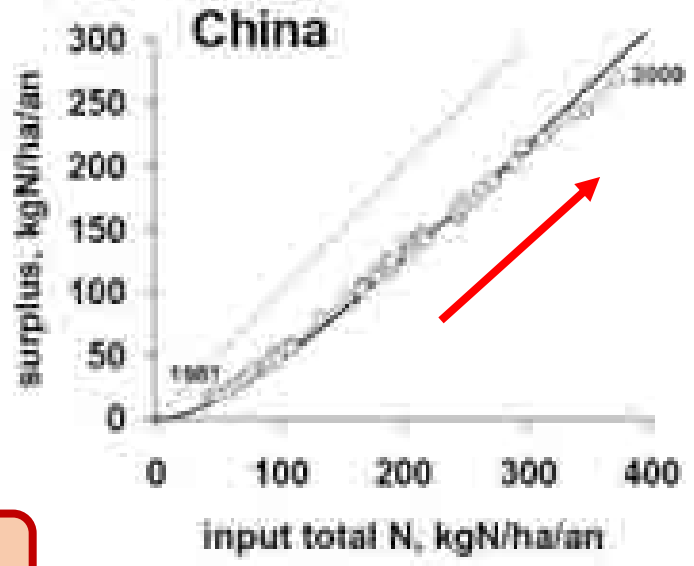


Quemada et al. 2020 (Agr. Syst.)

5. Efficiencies: Contrasting trends of world countries

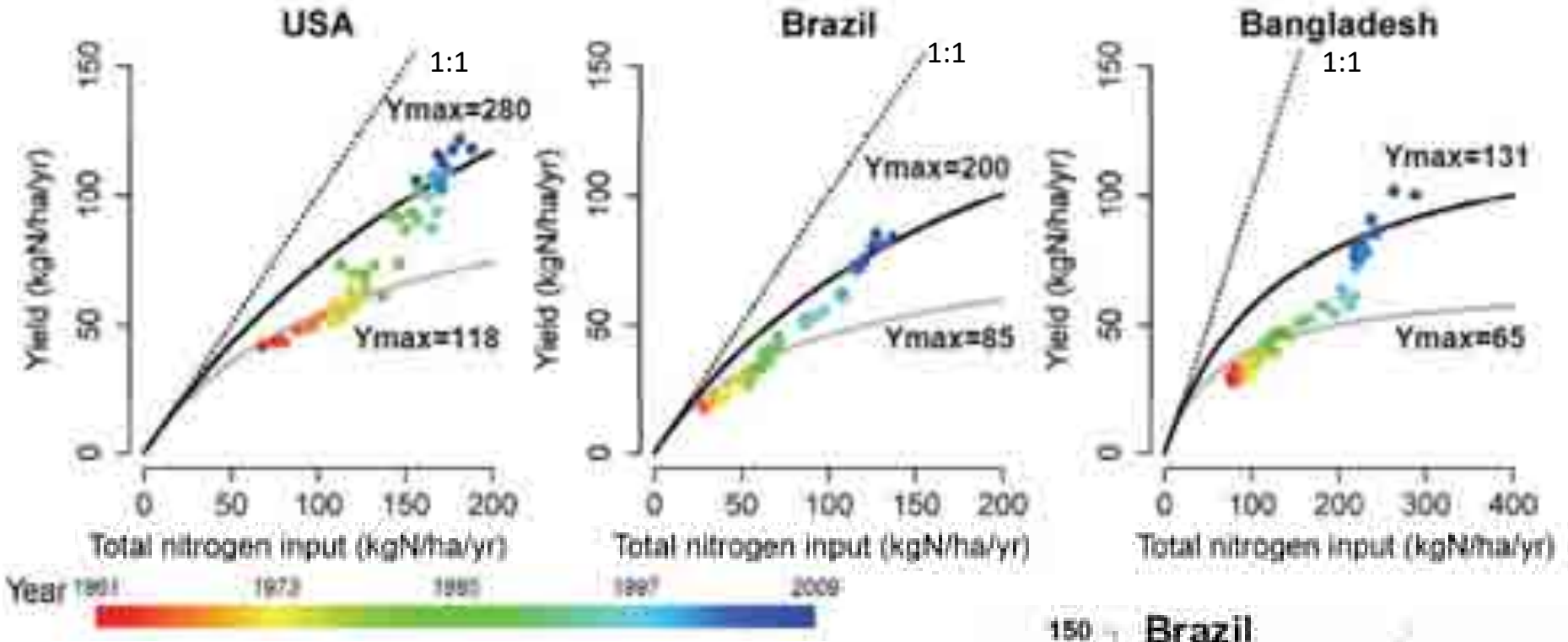


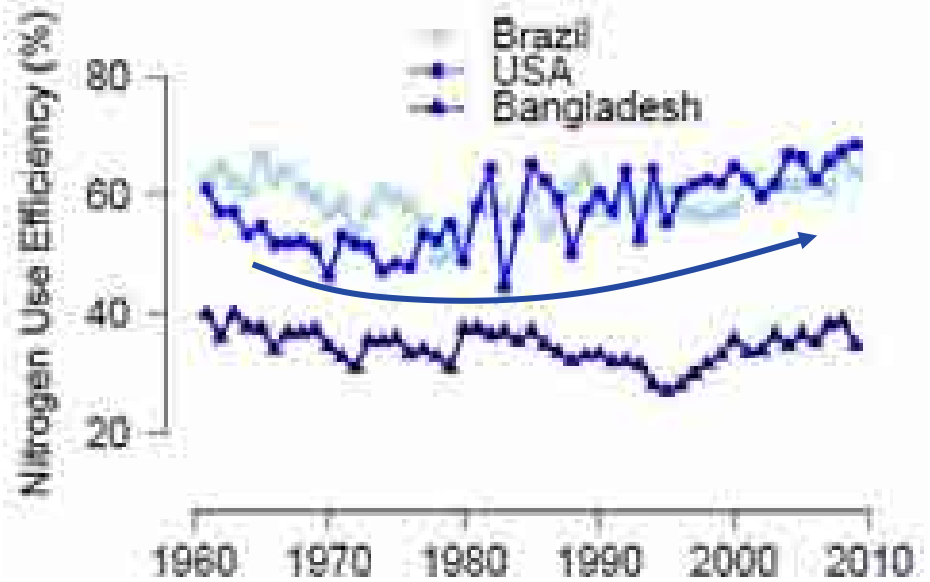


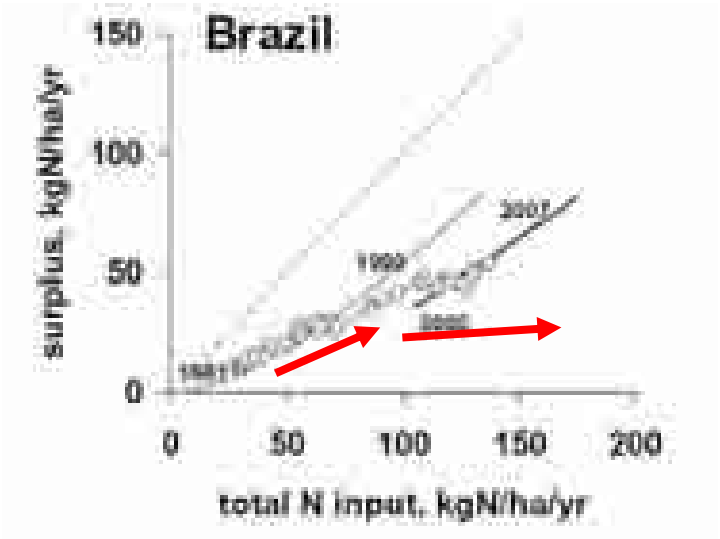


Type I

Lassaletta et al. 2014 (Environ. Res. Letters)

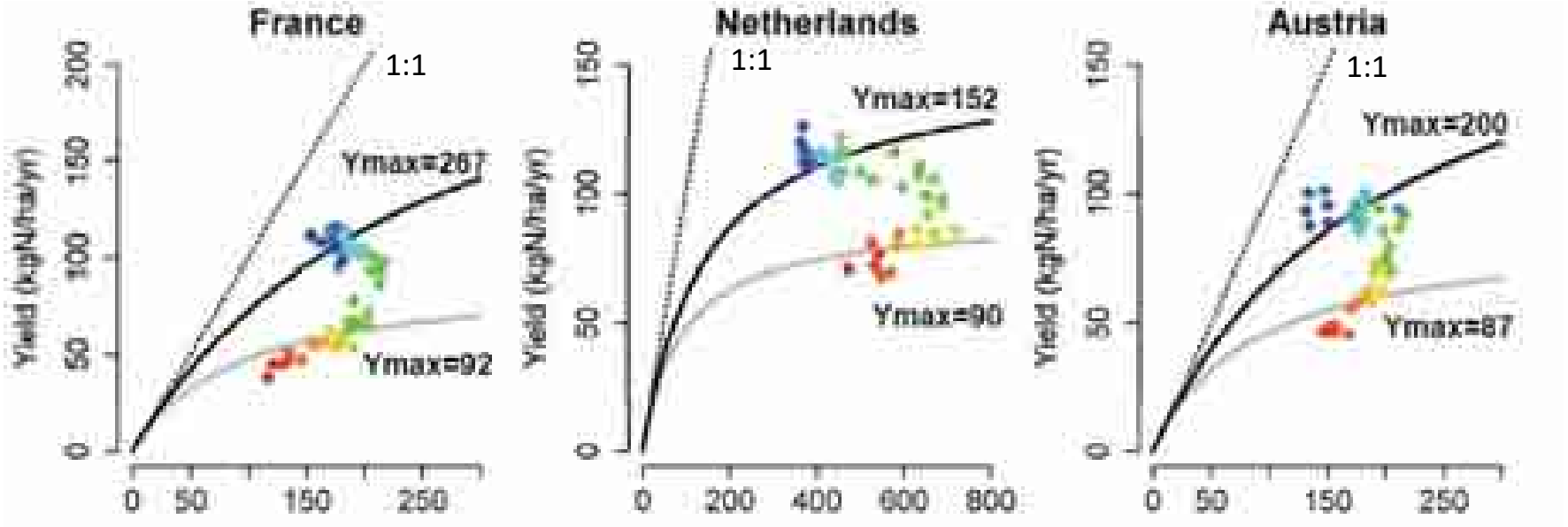


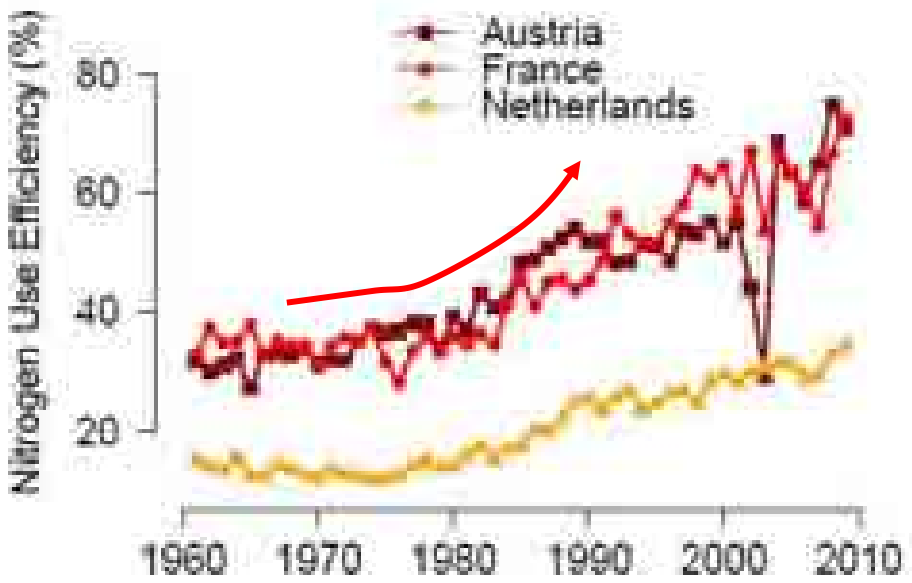


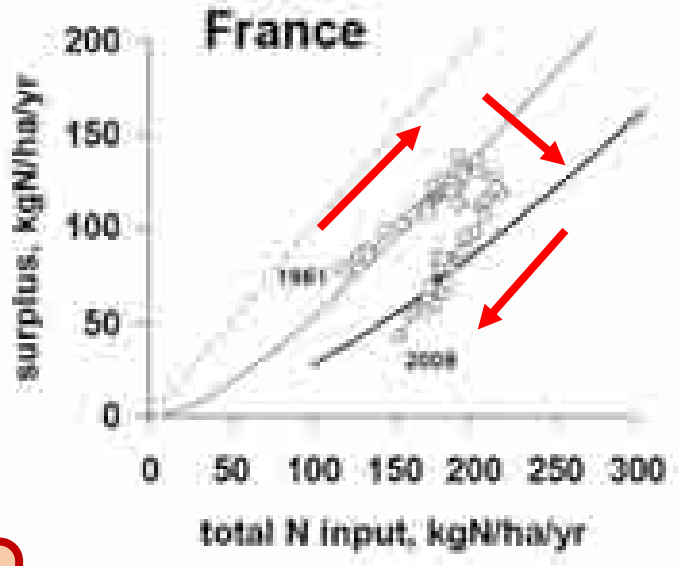


Type II

Lassaletta et al. 2014 (Environ. Res. Letters)

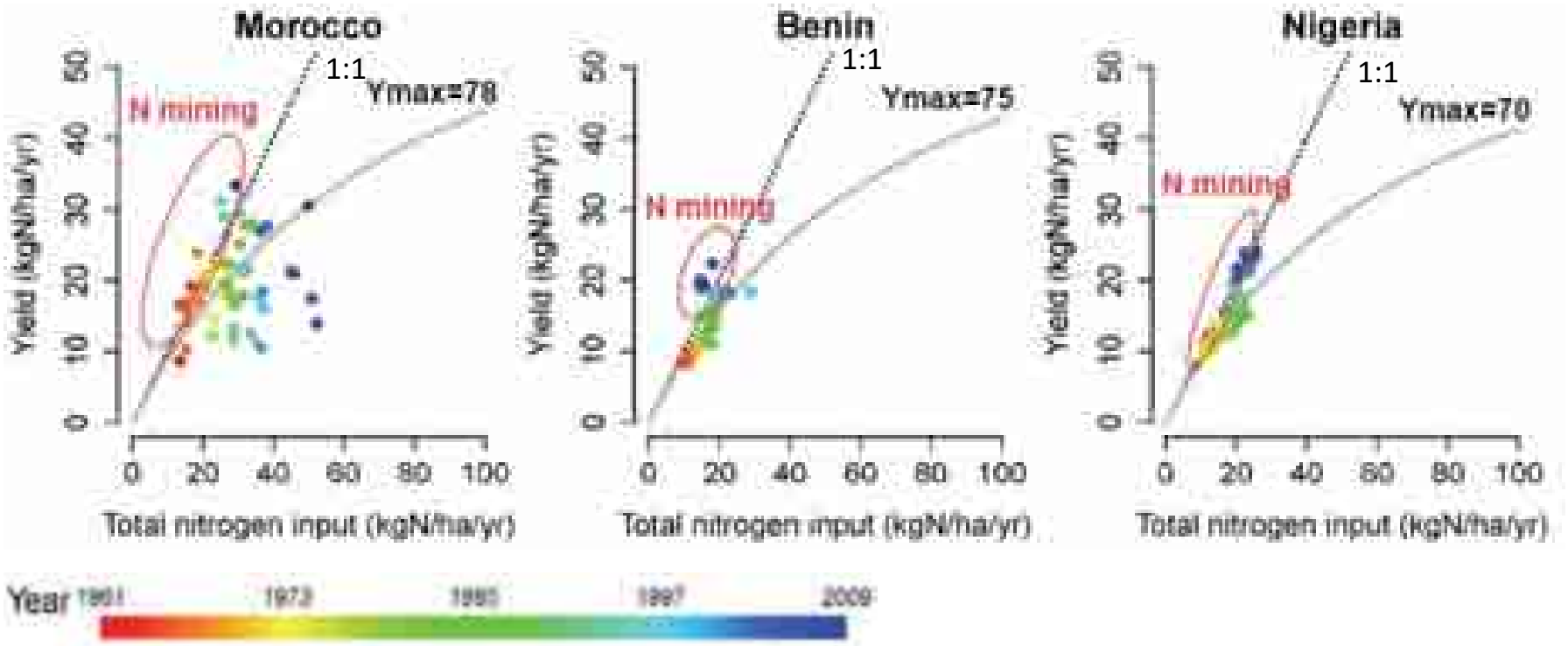






Type III

Lassaletta et al. 2014 (Environ. Res. Letters)

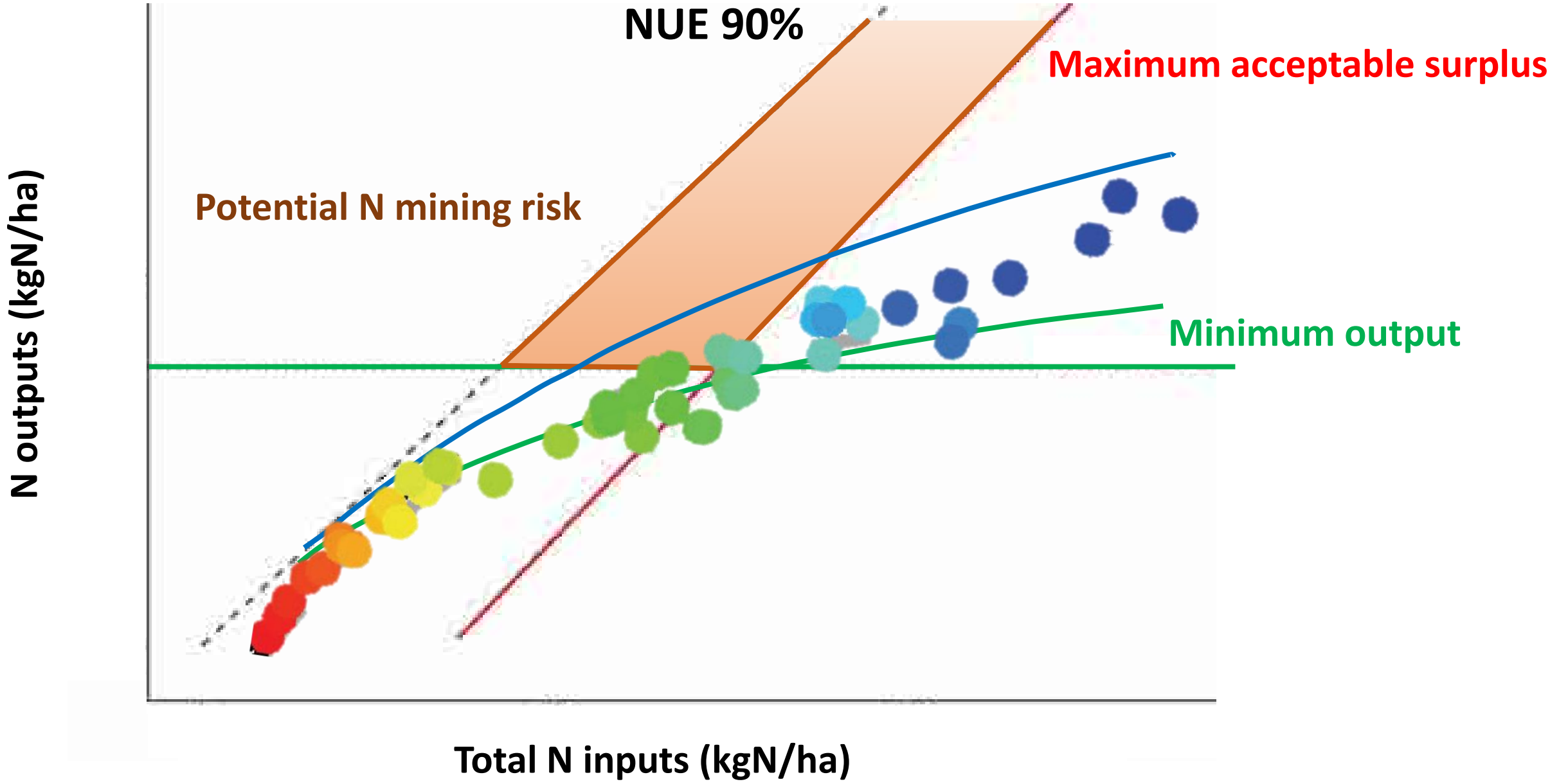


Type IV

Lassaletta et al. 2014 (Environ. Res. Letters)

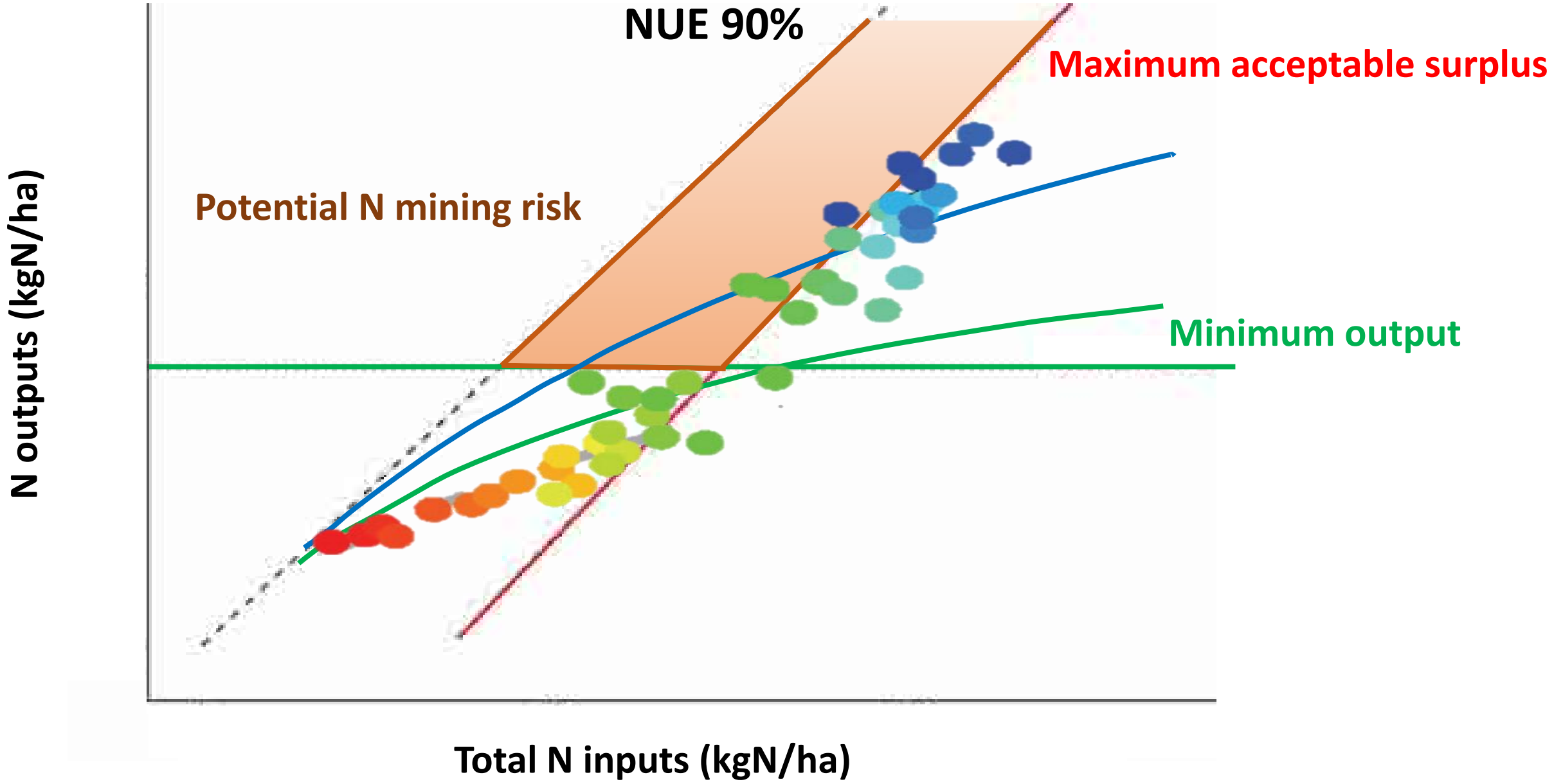
Type I

e.g. China



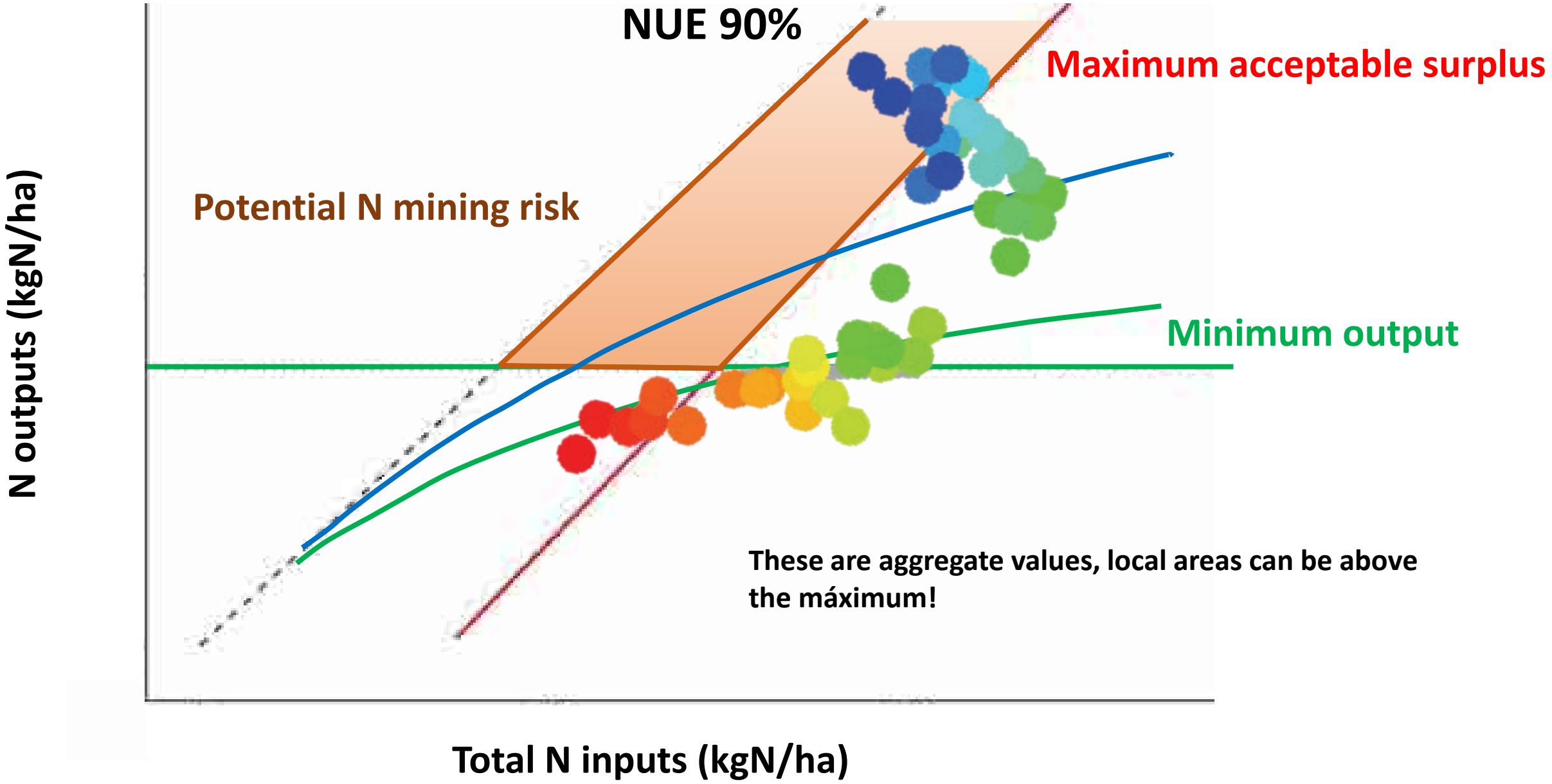
Type II

e.g. USA



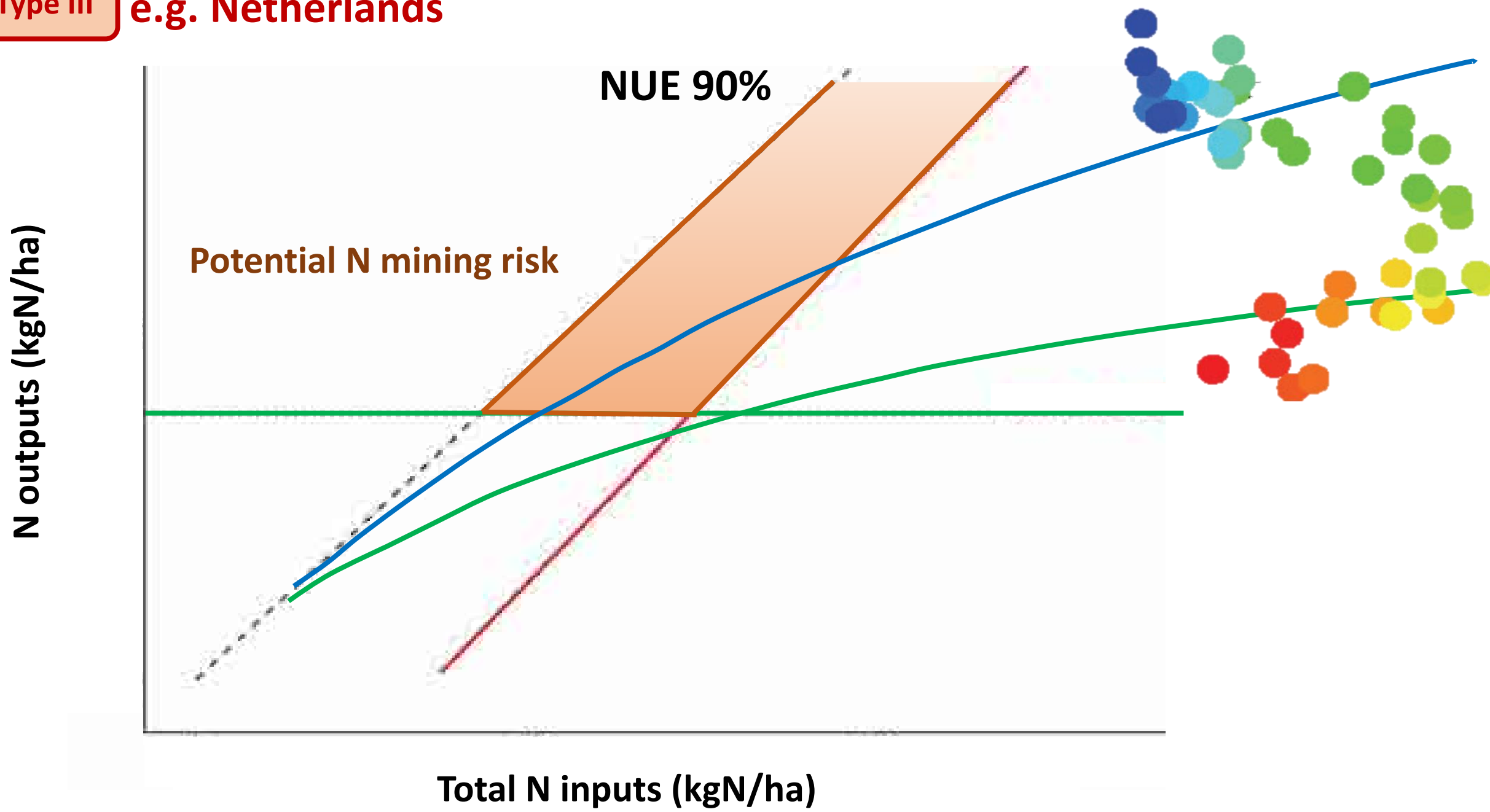
Type III

e.g. France



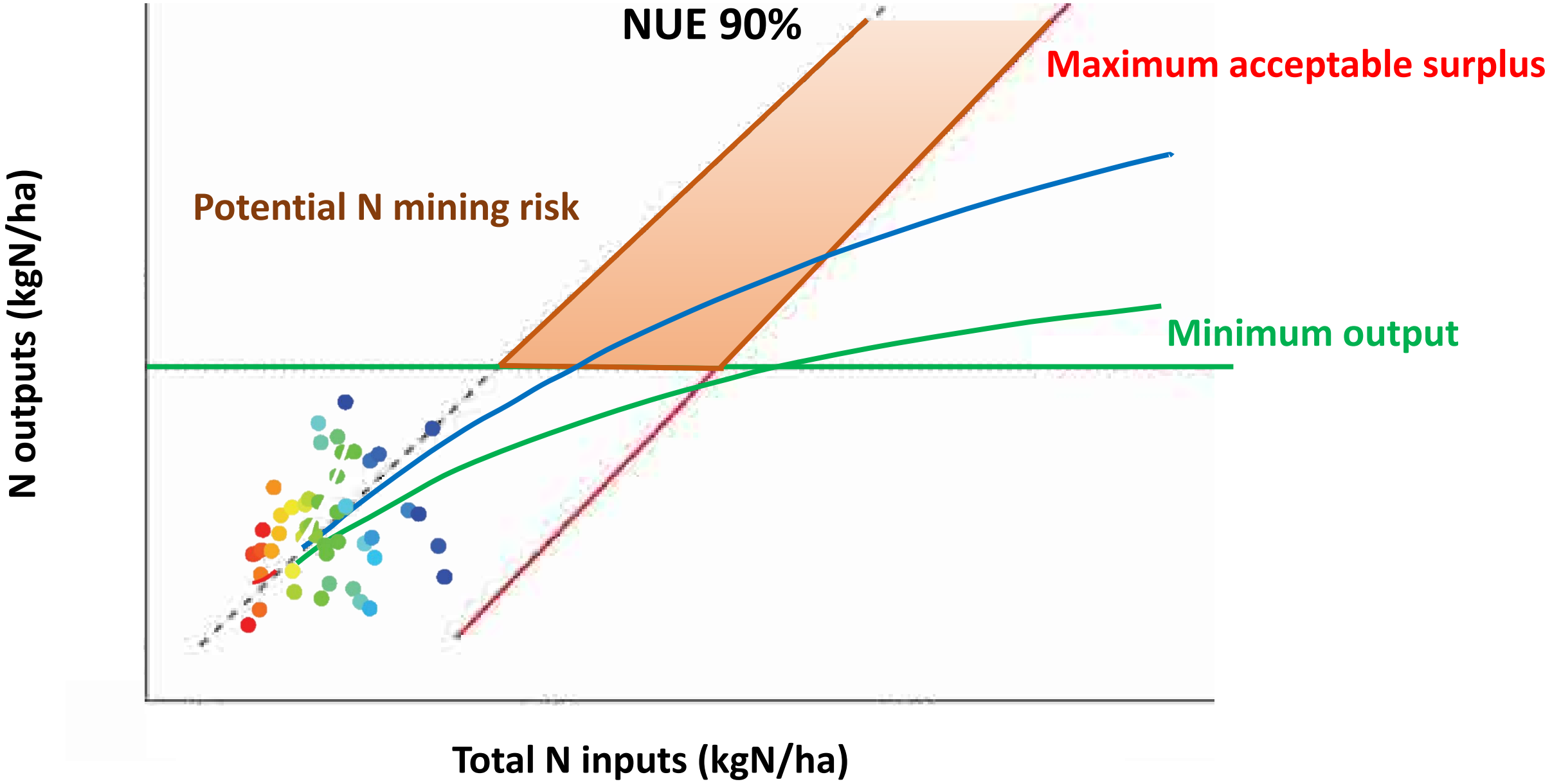
Type III

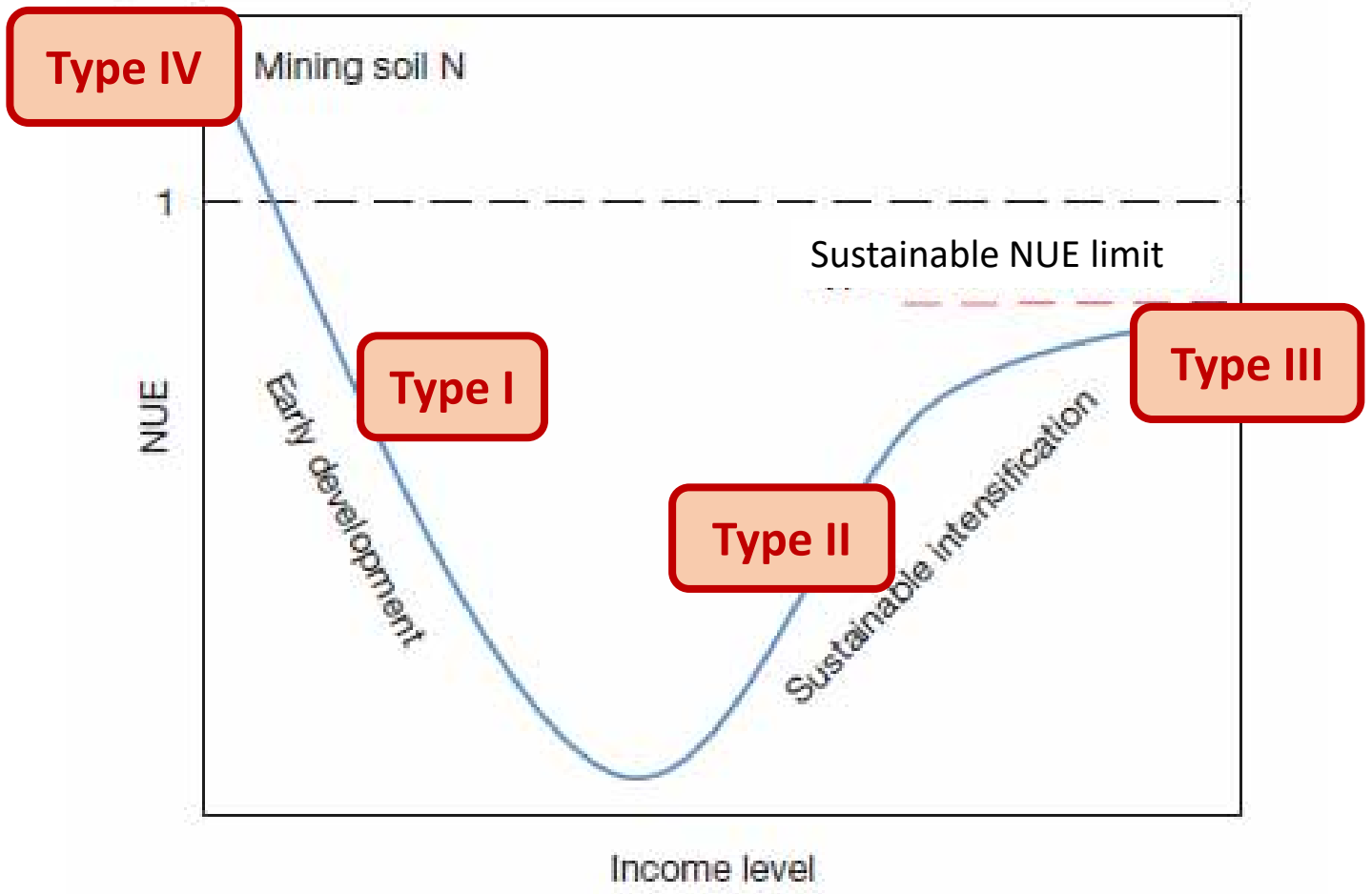
e.g. Netherlands



Type IV

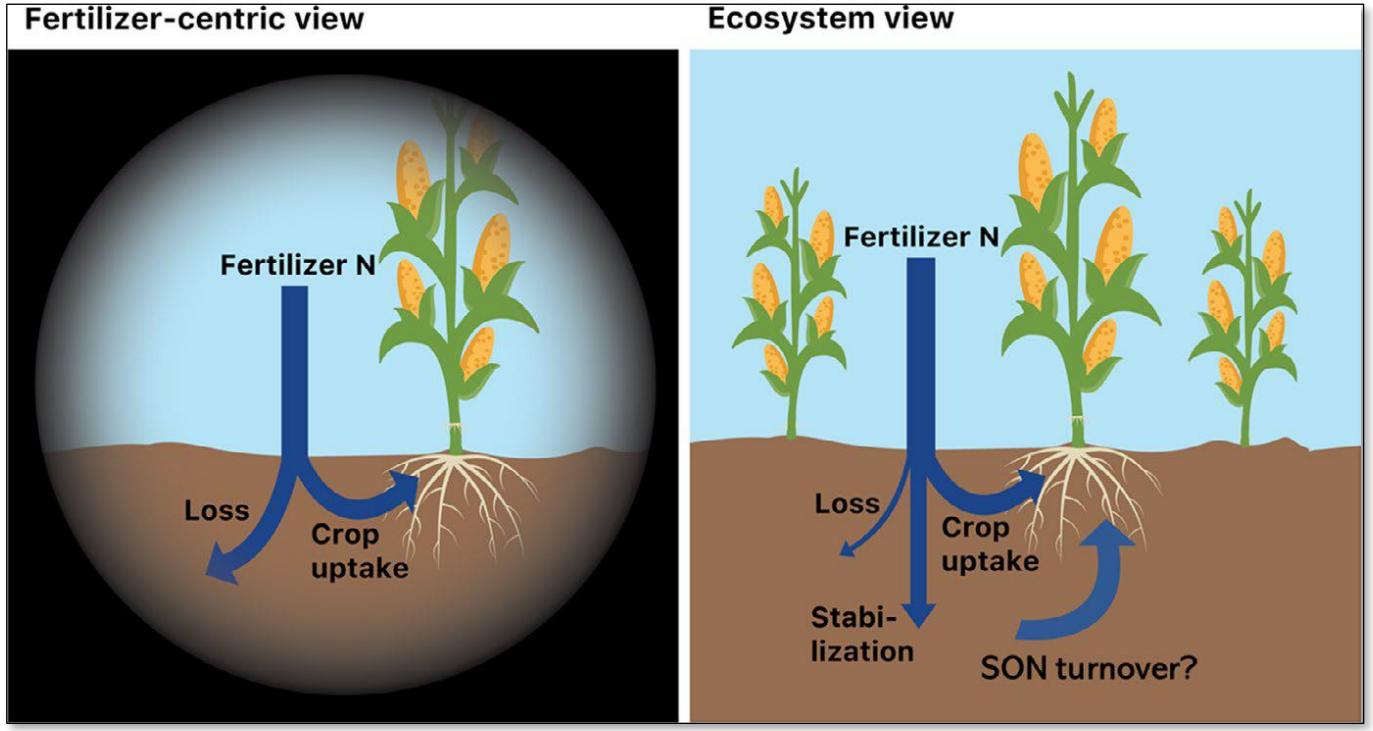
e.g. Morocco





Zhang et al. 2015, Nature

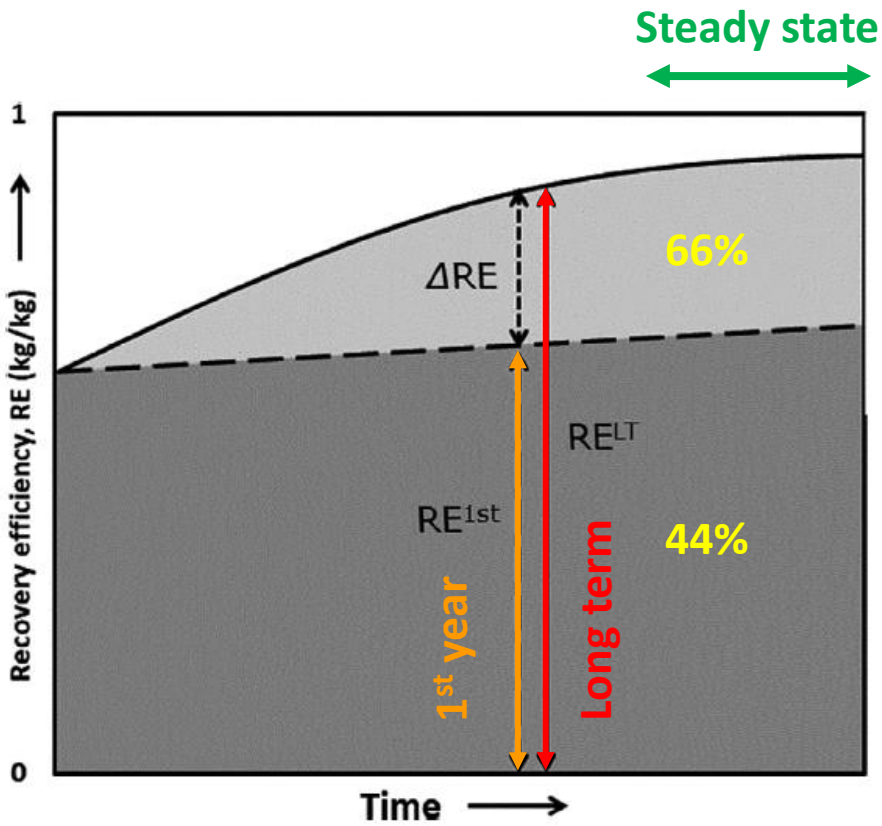
6. Rotations, nutrient legacies and crop mix



Only 30-44% of fertilizer applied is recovered the same year
Residual effect can represent a non-negligible contribution

Yan et al. 2019 (GCB)
Quemada et al.2019 (EJA)

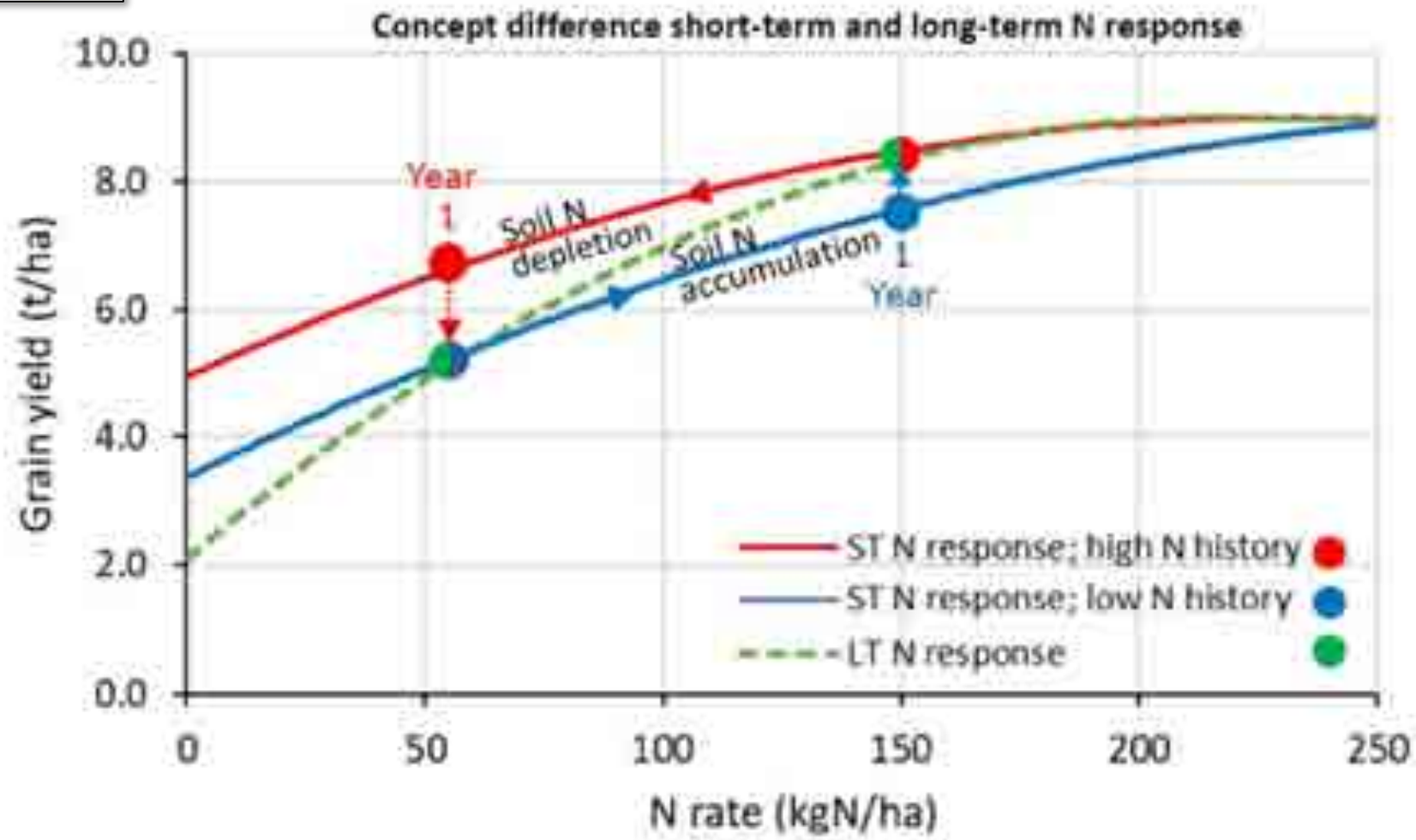
Long term trials



Vonk et al. 2022 EJ. Soil Science

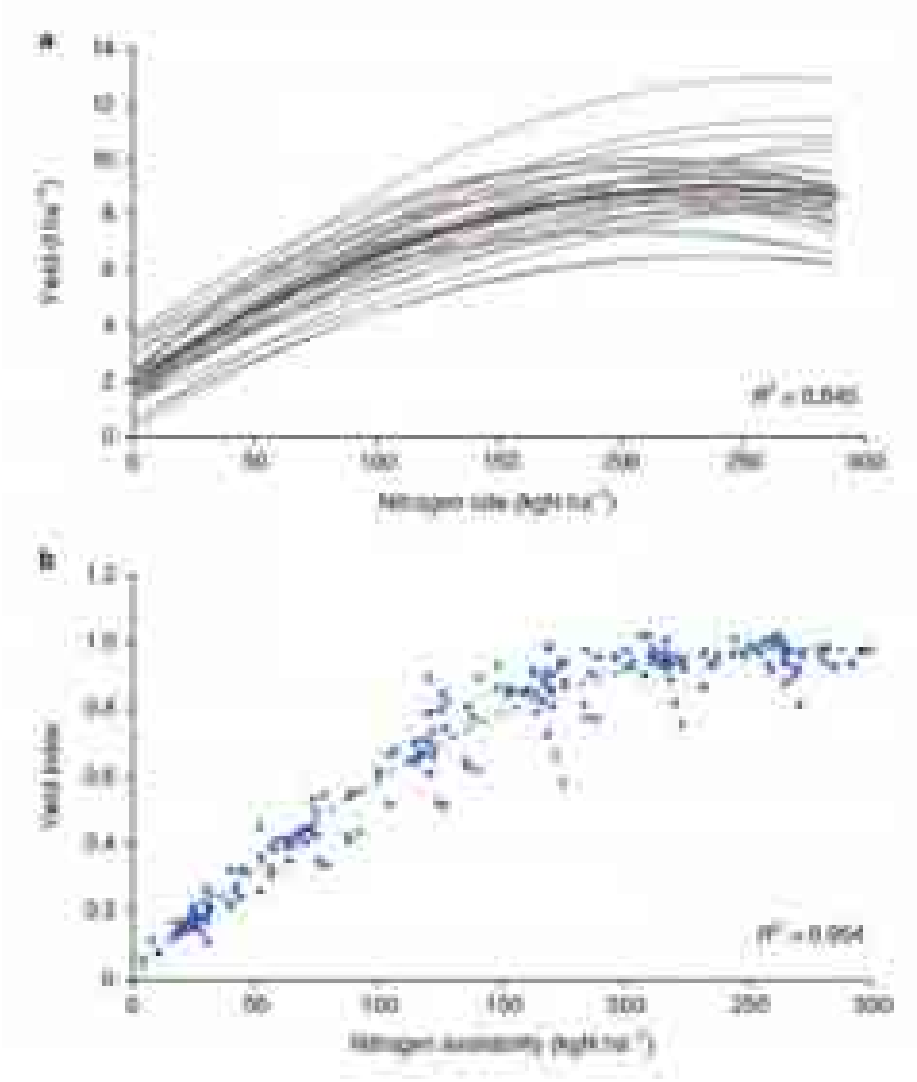

Establishing long-term nitrogen response of global cereals to assess sustainable fertilizer rates

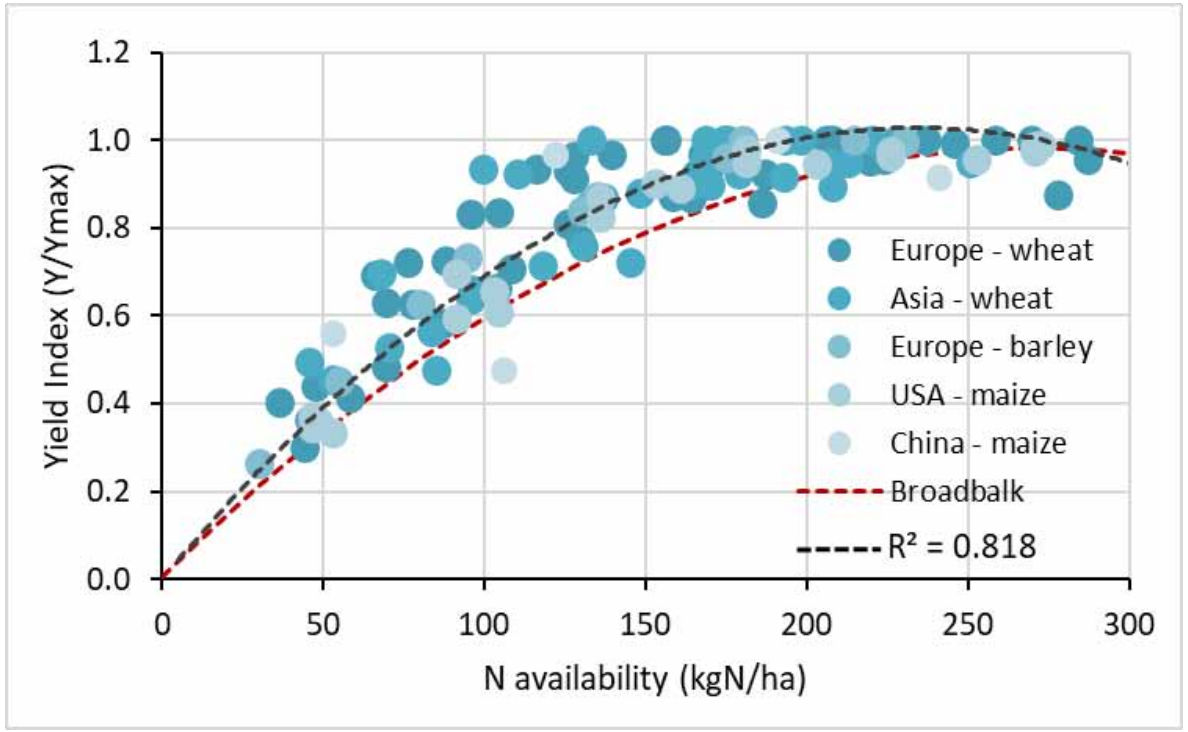
25 Long-Term cereal trials



Van Grinsven et al., 2021 (Nature Food)

Long-term unscaled N response for 25 LTEs



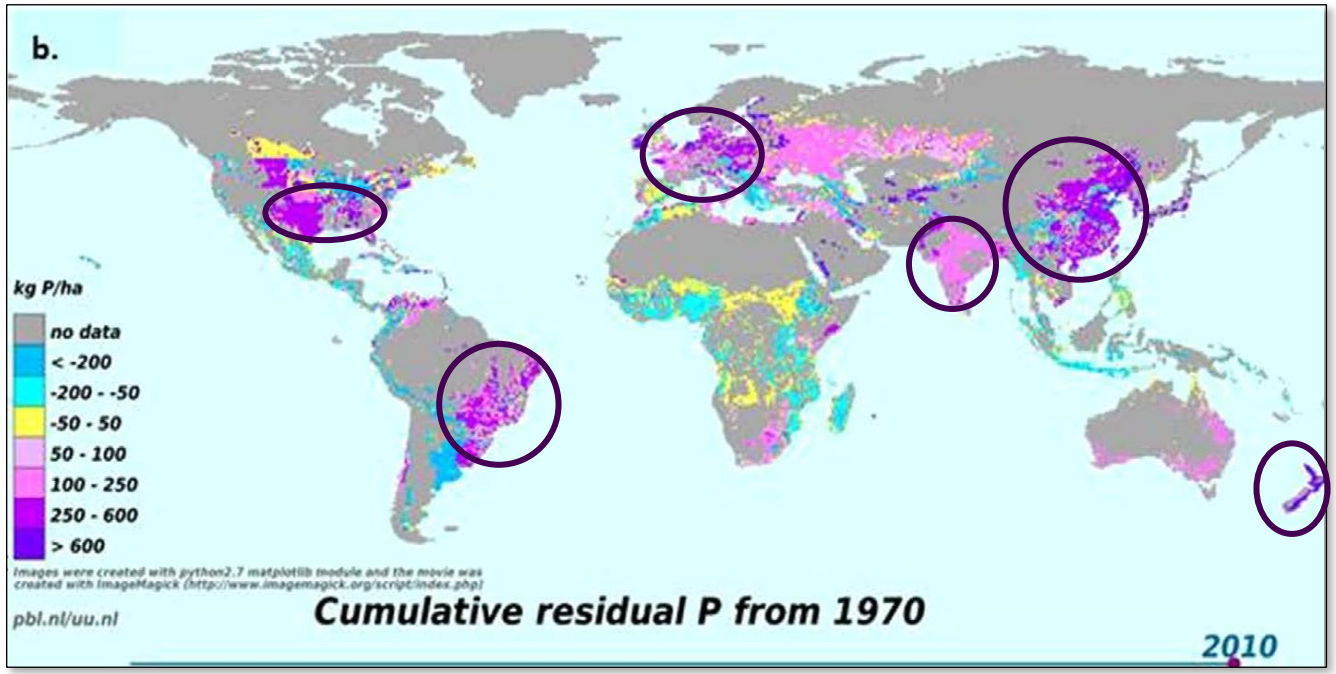


Adoption of LT curves has important implications on the estimation of N needs

Van Grinsven et al., 2021 (Nature Food)

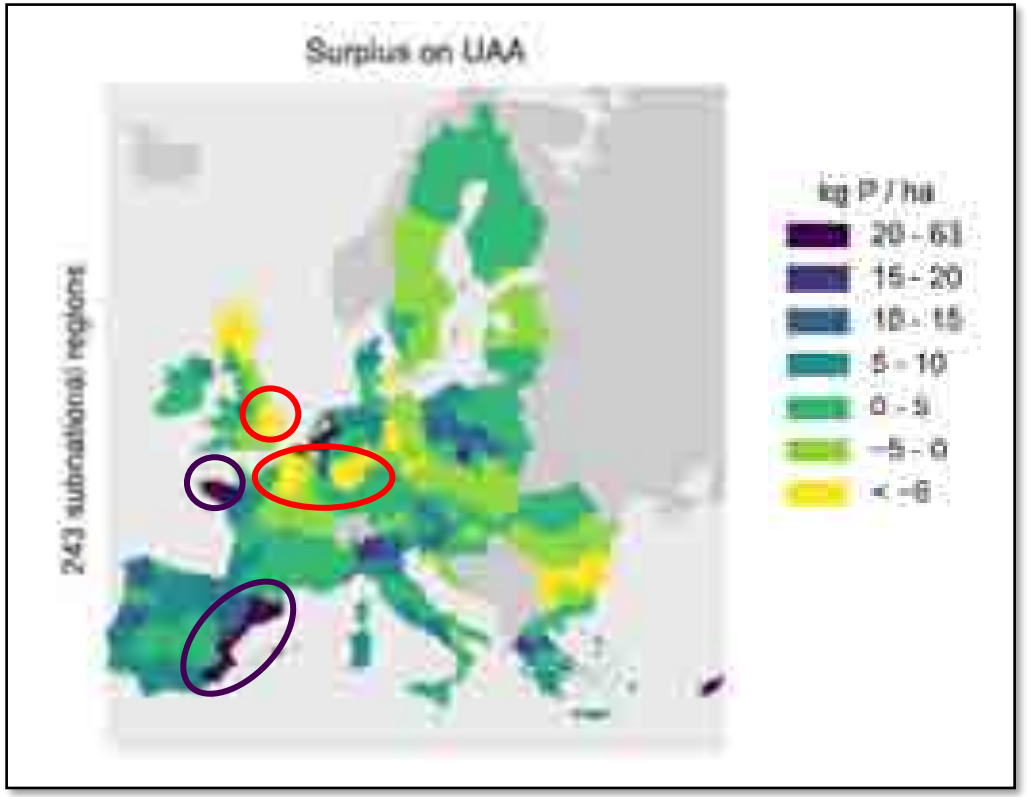
6. Rotations, nutrient legacies and crop mix

Strong accumulation of P that can be reused during decades



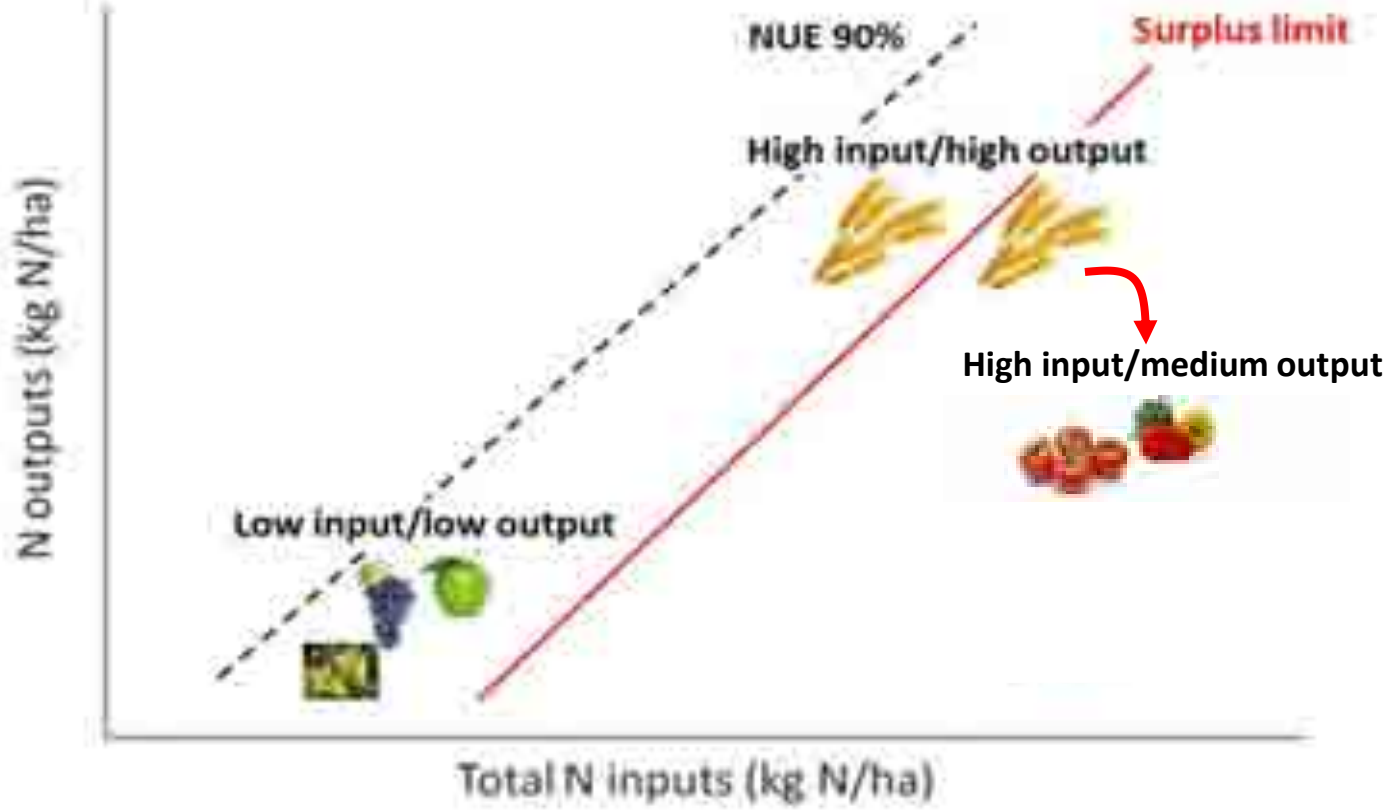
Bouwman et al. 2017 (Sci. Rep.)

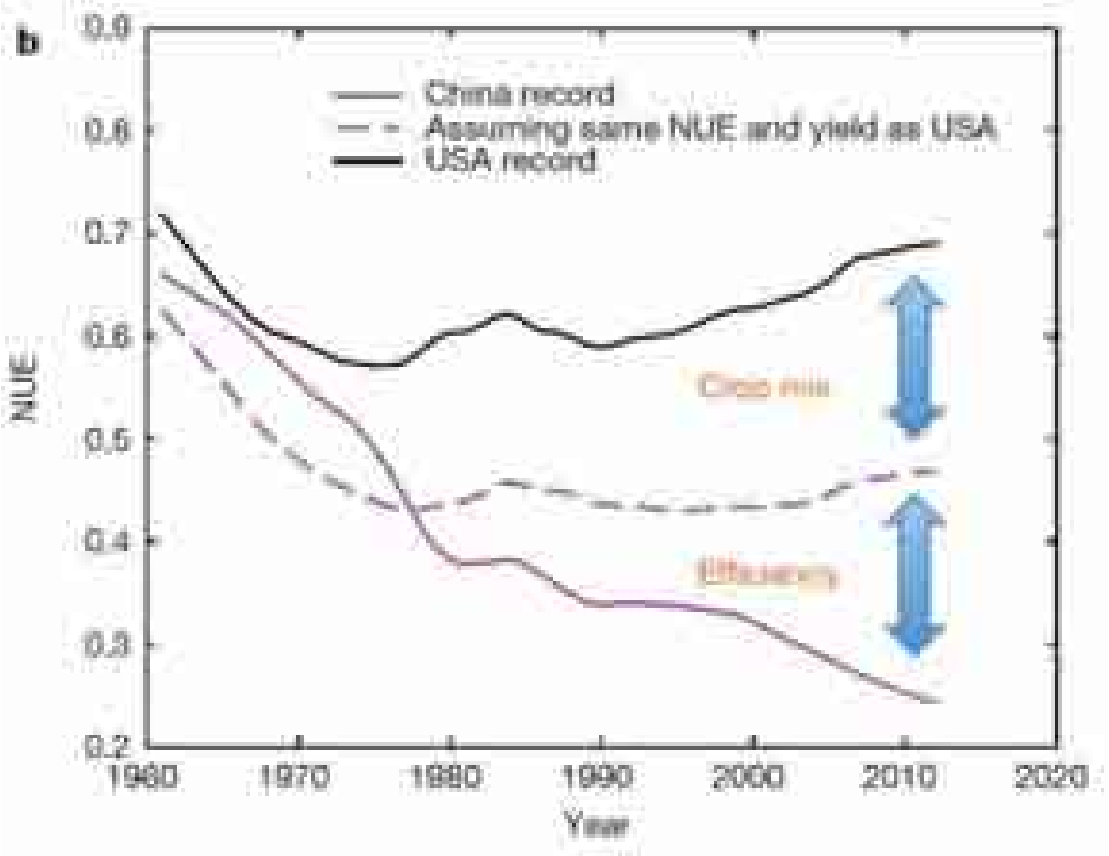
Some regions in EU are using this legacy while other regions are still accumulating



Einarsson et al. 2017 (Sci. Rep.)

6. Rotations, nutrient legacies and crop mix





Hayashi et al. 2022 (INMS In press)

Zhang et al. 2015 (Nature)

7. Future global scenarios

The Shared Socioeconomic Pathways

	SSP1 Sustainability	SSP2 Bussines as usual BAU	SSP3 Fragmentation	SSP4 Inequality	SSP5 Fossil fuelled developed
Population (2100; billion)	7 Lowest	9.1	12.8 Highest	9.5	7.4
GDP	↑↑	↑↑	|	Unequal	↑↑↑
Environmental concern	↑↑↑	↑↑	|	Unequal	↑↑
Crop productivity	↑↑↑	↑↑	|	Unequal	↑↑↑
Livestock efficiency	↑↑↑	↑↑	|	Unequal	↑↑↑
Meat consumption	↓↓↓	|	↑↑	|	↑↑↑

Van Vuuren et al. 2012 (Clim. Change)

	SSP1 Sustainability	**SSP2** **BAU**	**SSP3** Fragmentation	**SSP4** Inequality	**SSP5** Fossil fuelled developed
NUE	60%-70%-85% Based on Zhang et al. (2015) targets	Based on curves	Based on curves	Based on curves	Based on curves
Ymax	From NUE	GDP curves	Almost stagnated	Wealth dependent	GDP curves
Manure	Fully to crops	As previous	As previous	As previous	As previous

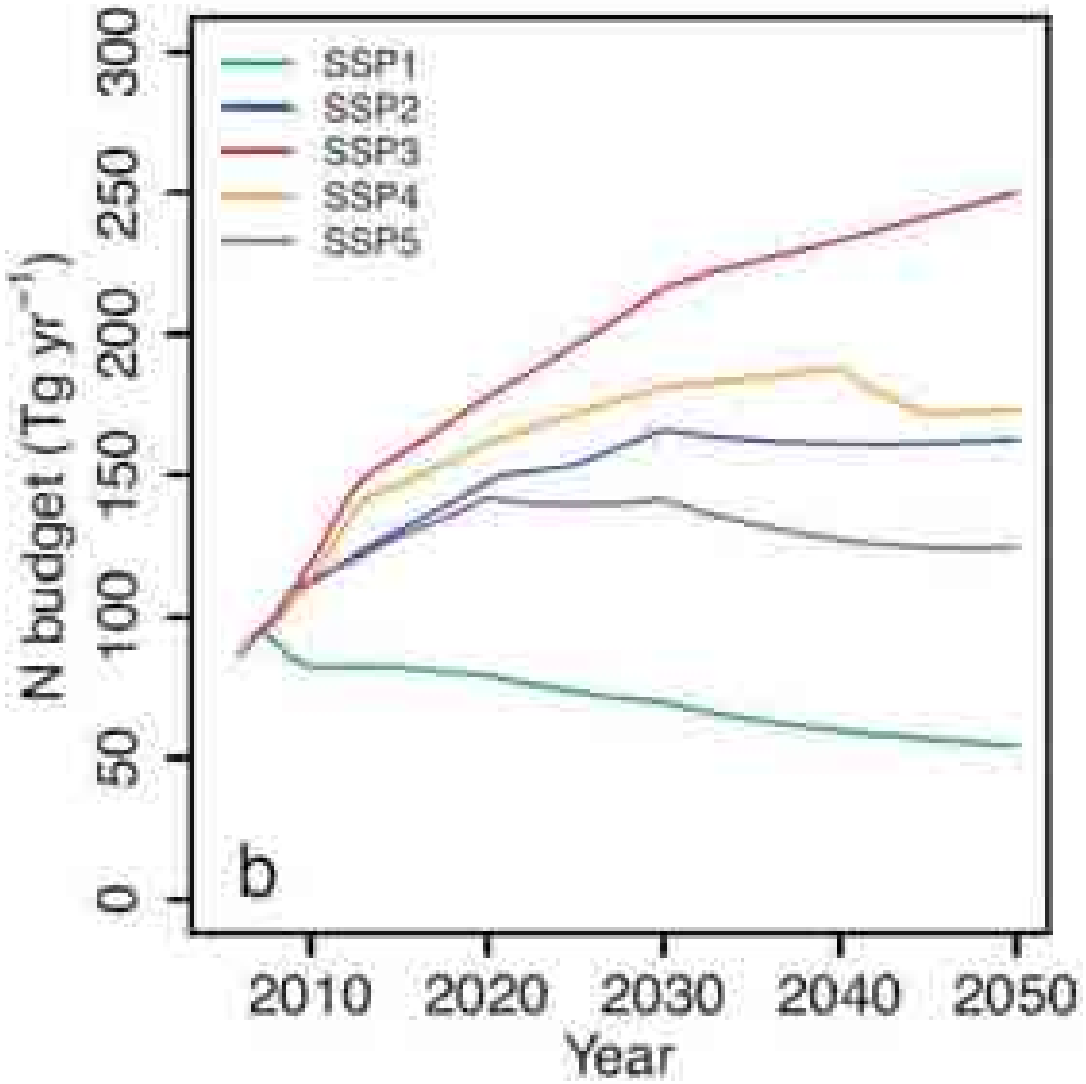
NUE max 85%

NUE min 20%

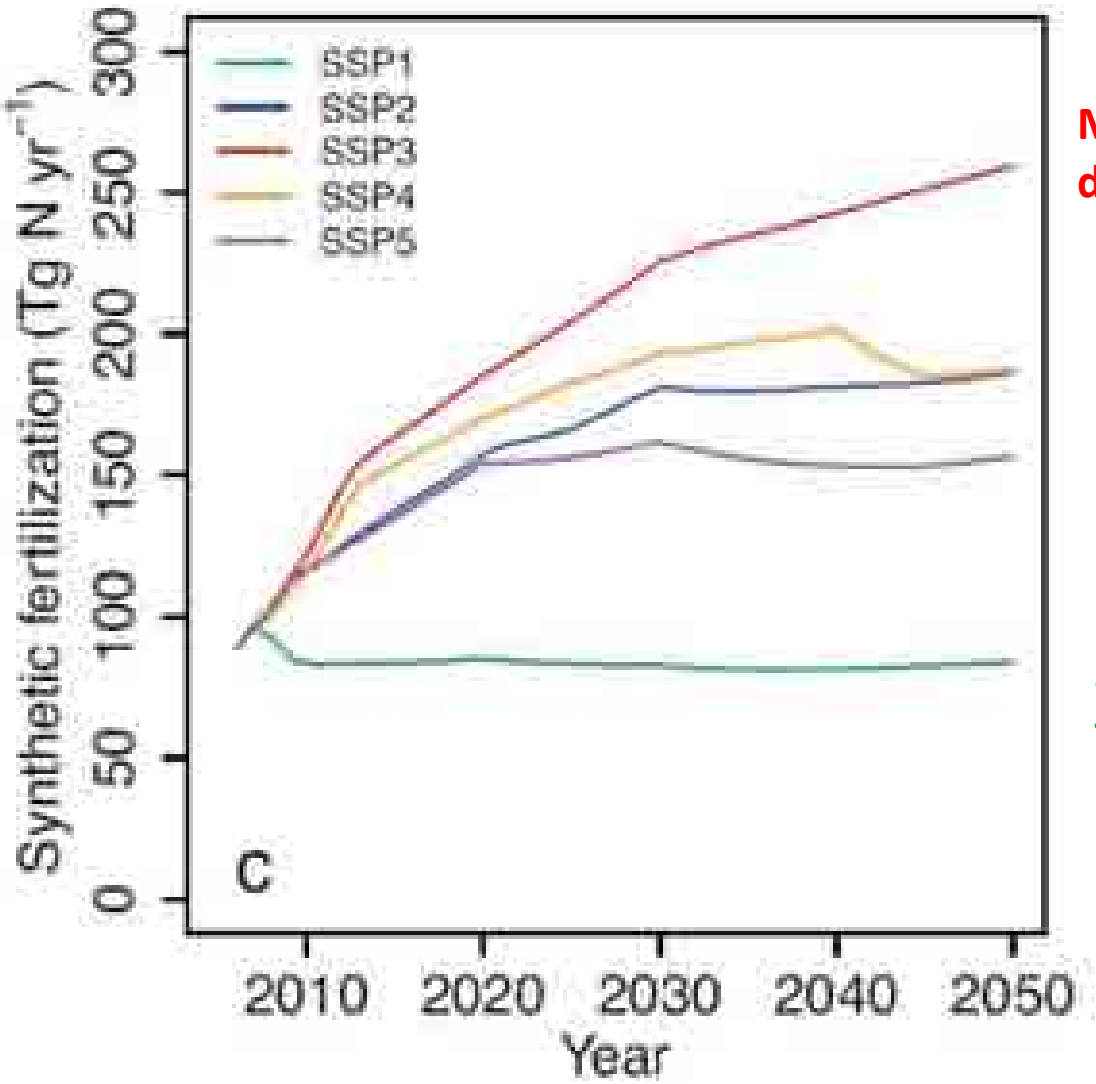
Mogollón et al., 2018 (ERL)

7. Future scenarios

N surpluses



Haber Bosch

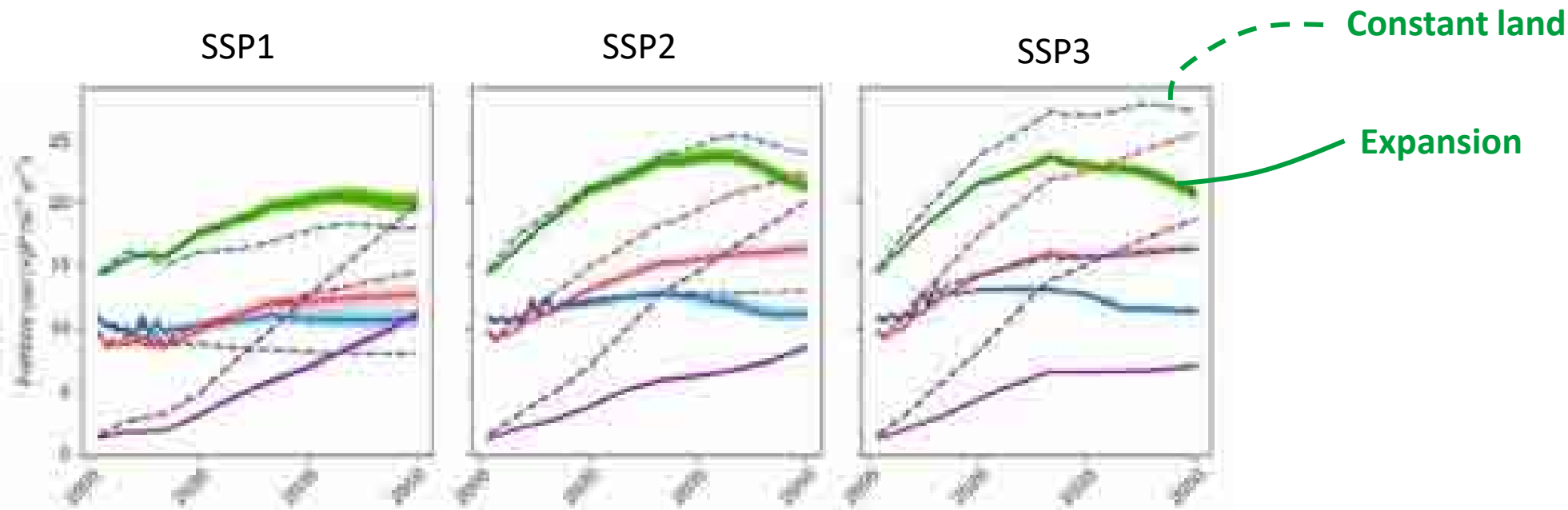


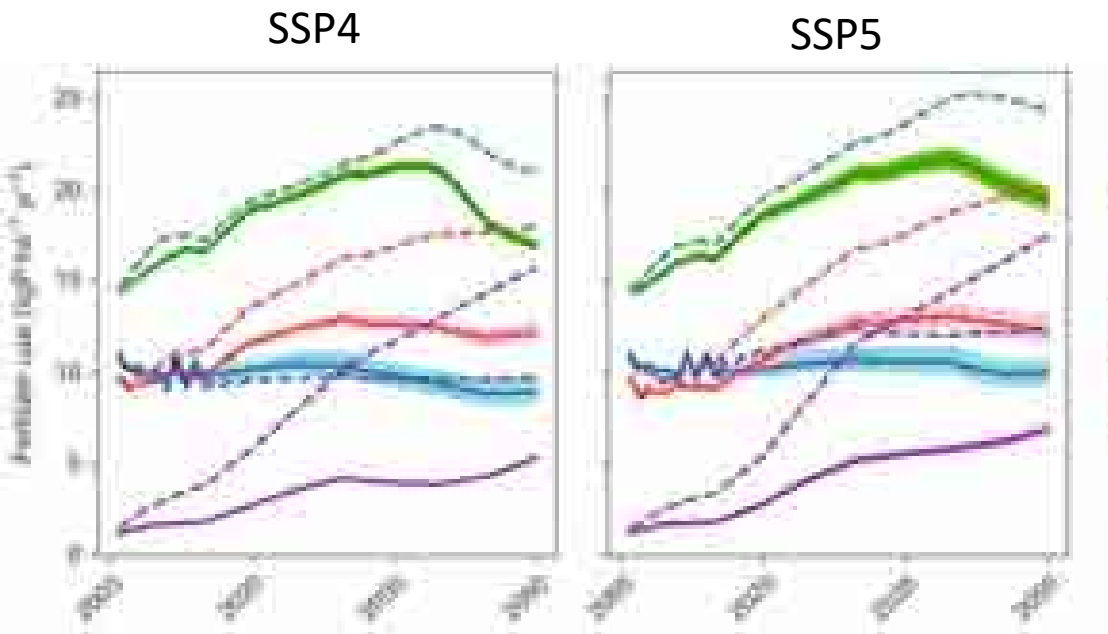
More than double!

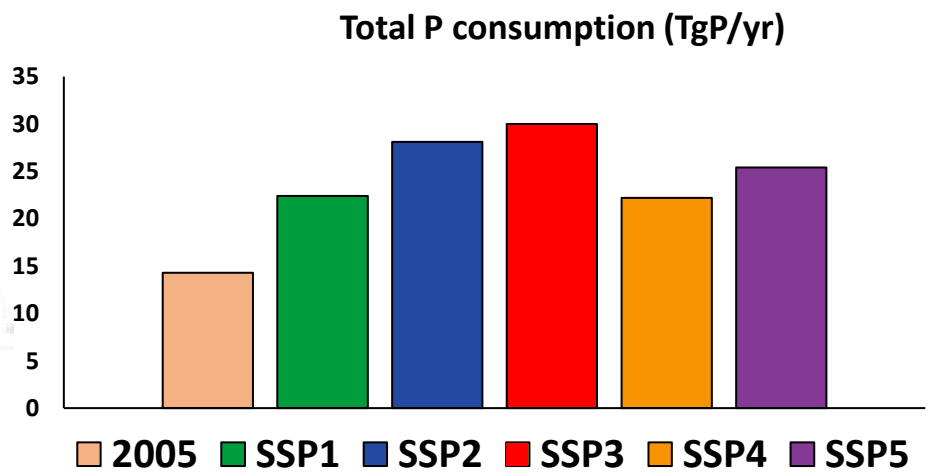
Slightly lower than today

Mogollon et al. 2018 (ERL)

7. Future scenarios



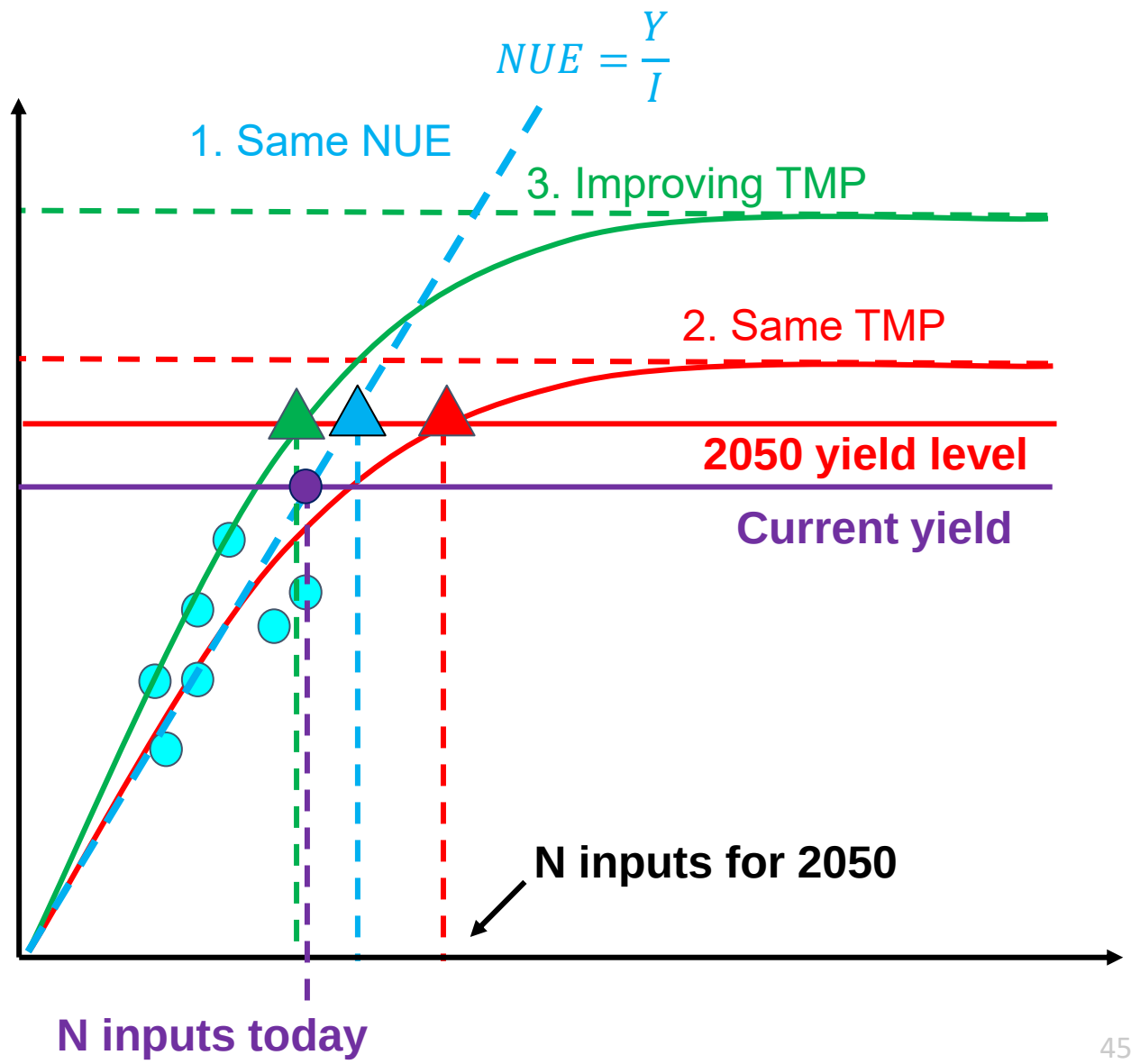




Mogollon et al. 2021 (Nature Food)

Approach for projecting N inputs in cropland

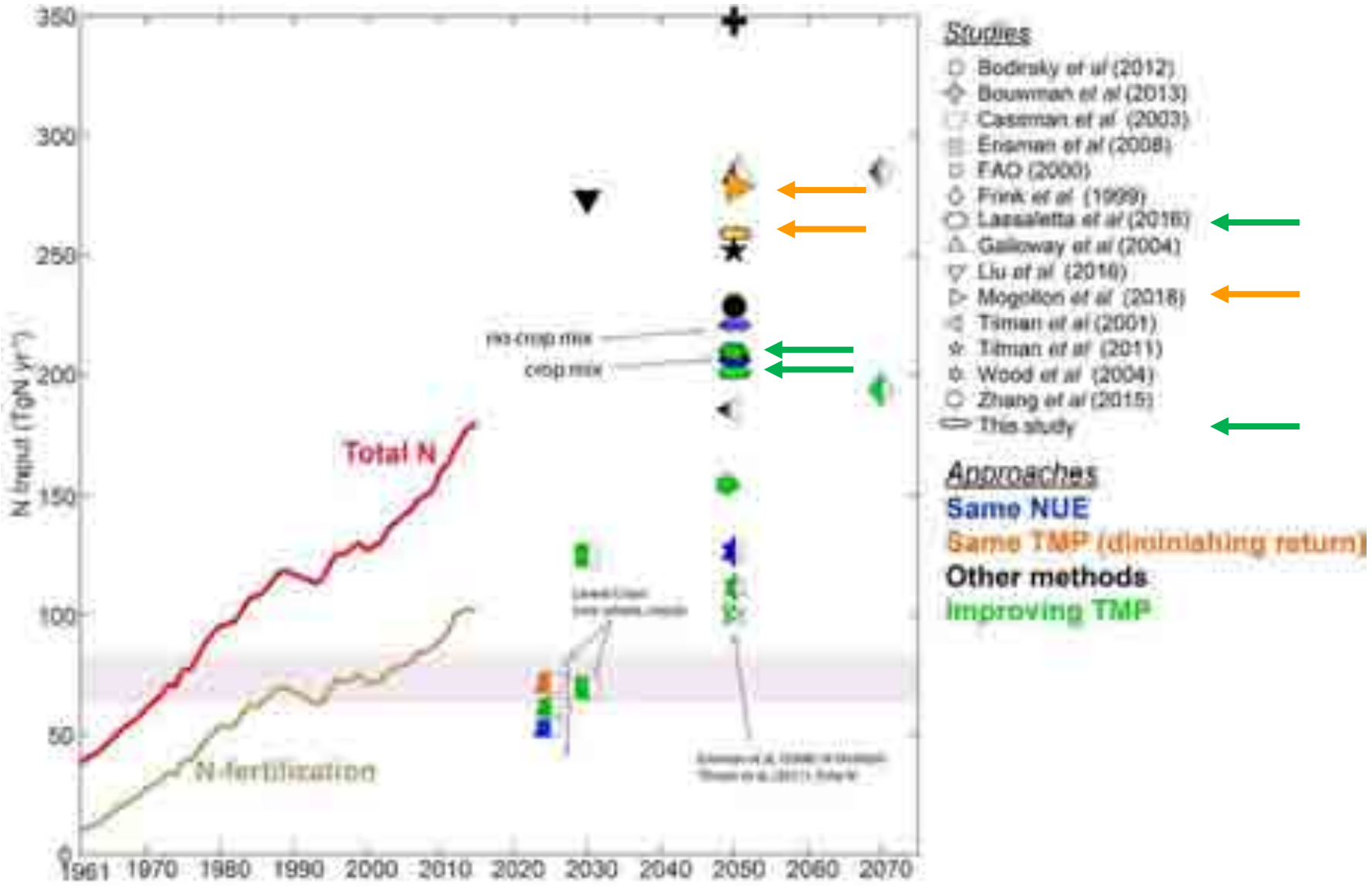
- ***Three scenarios are designed***
- Yield response function: One-parameter hyperbolic
- Estimating N inputs required for 2050 food demand



NUE: Nitrogen use efficiency, yield/inputs
Asymptote of hyperbolic curve
TMP: Technology and management practices

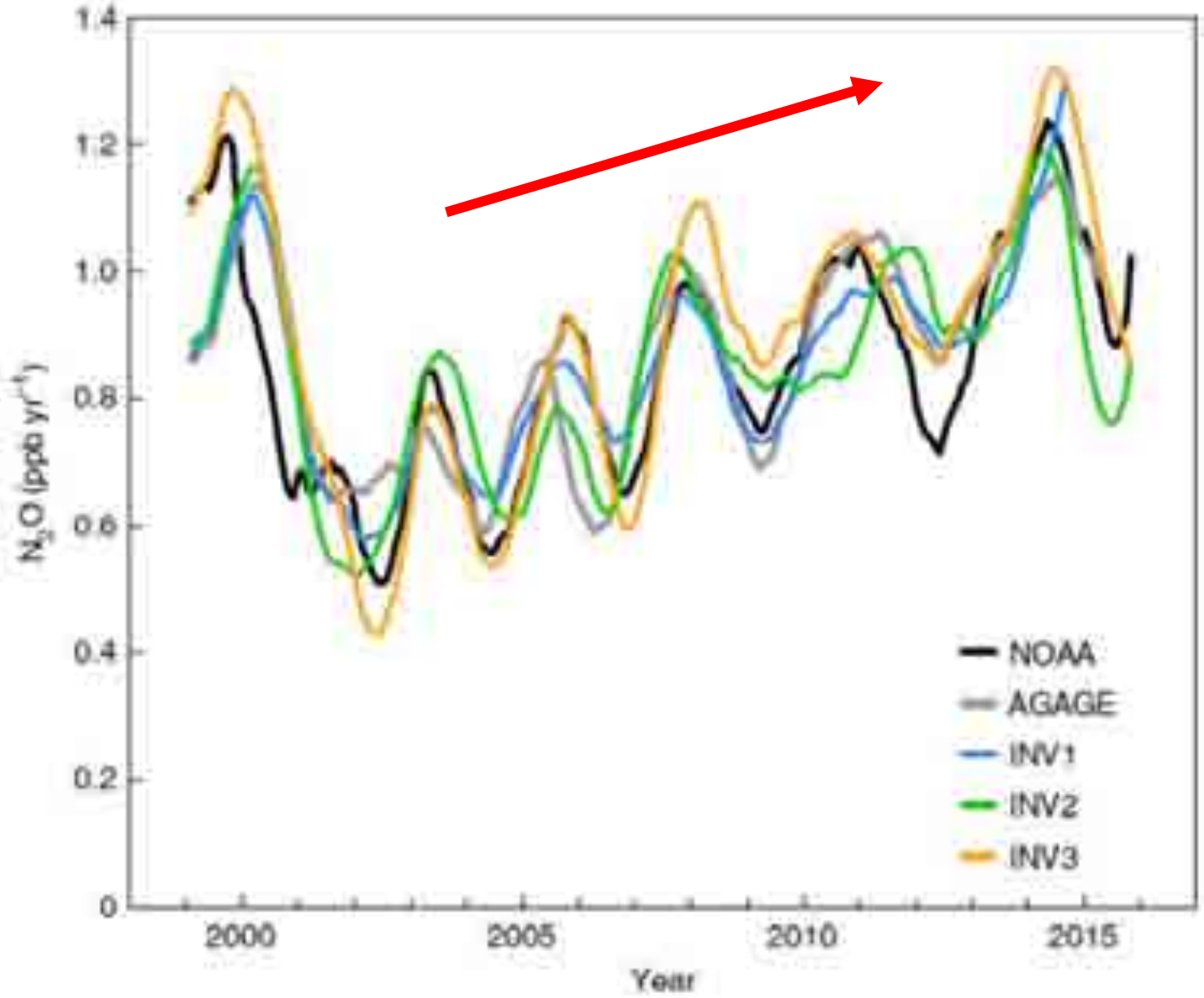
Vishwakarma, Zhang and Mueller 2022 (ERL)

Comparison of global N projection



Vishwakarma et al. 2022 (ERL)

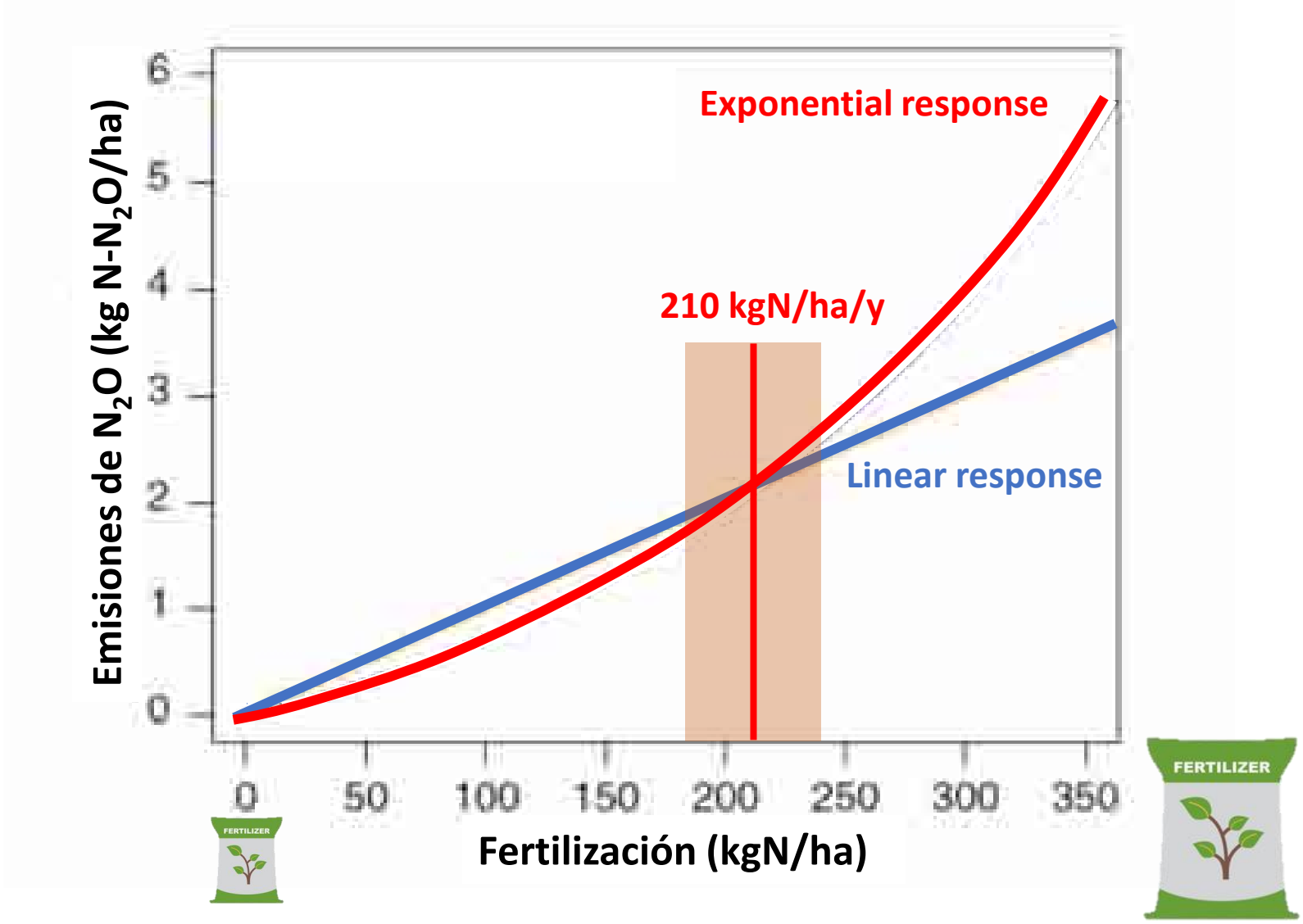
Growth rates of N_2O



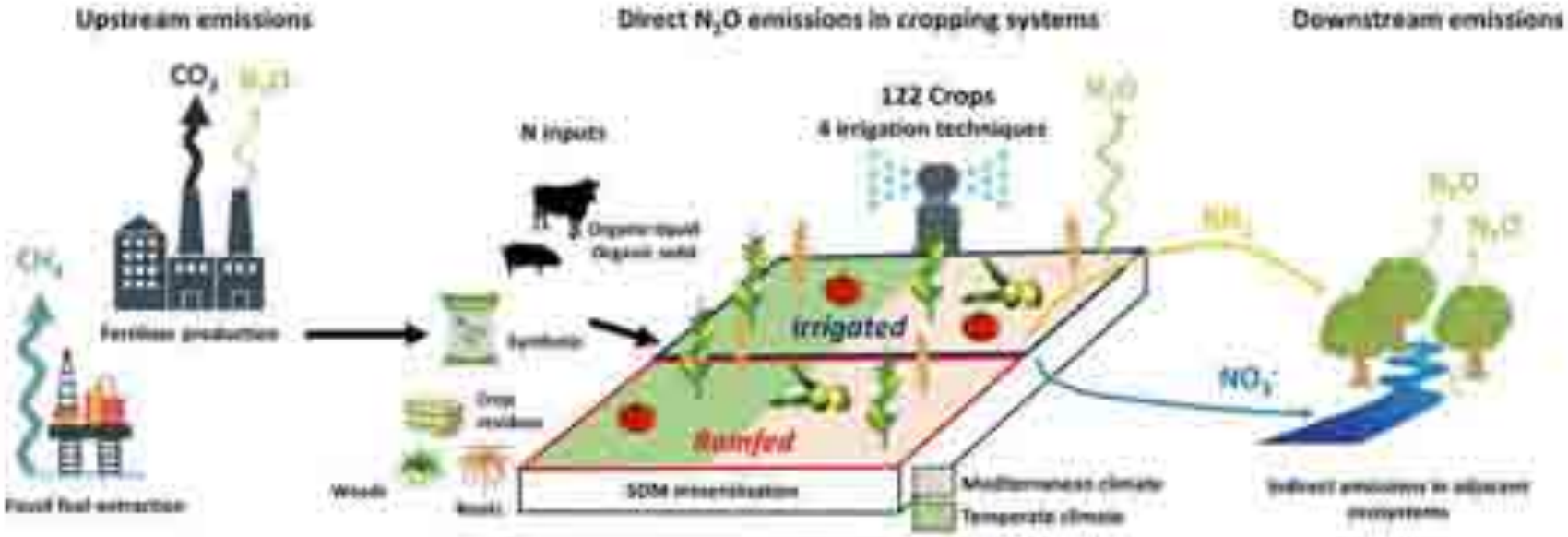
Thompson, Lassaletta et al. 2019 (Nat. Climate Change)

nature climate change
news & views

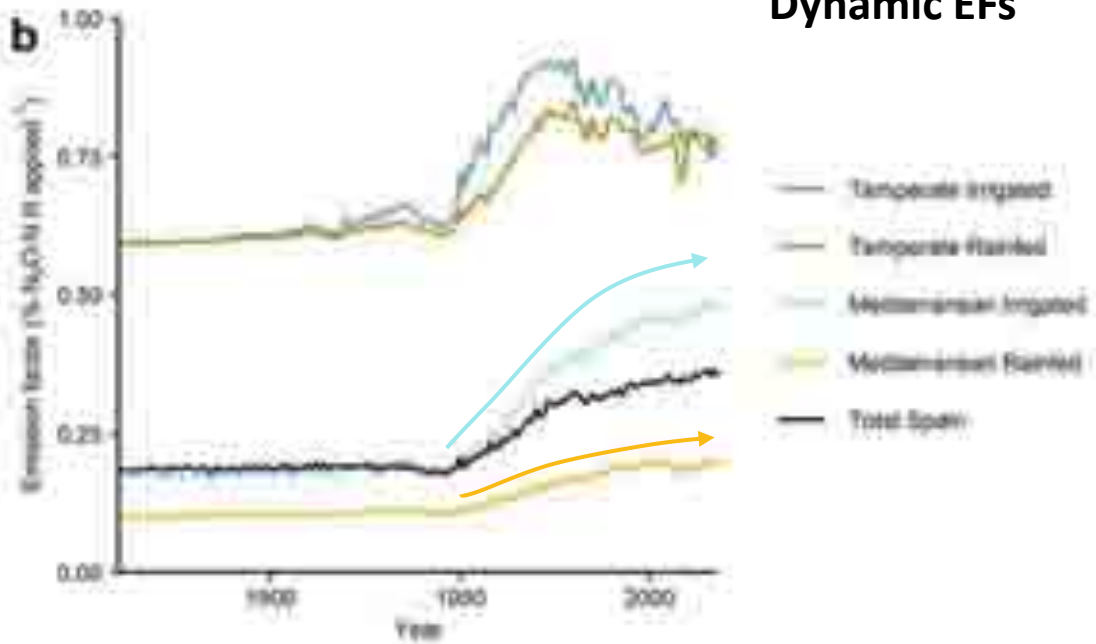
Linear response: Emission Factor
IPCC Tier-1: 1%



Makowski 2019 (Nat. Climate Change)



Dynamic EFs



Aguilera et al. 2021 (ERL)

Conclusions

- The **consumption** of synthetic fertilisers has increased **9-fold and 4-fold for nitrogen (N) and phosphorus (P)** during the past six decades promoting significant yield increases but also important environmental problems

- The **crop expansion** and **intensification** but also other drivers such as contrasting **efficiencies**, **crop mix**, **soil legacies** and **diverse structure of agro-food systems** have affected the observed trends regionally and globally.

- **The future** has to be written but the lack of a **coordinate action** at different levels and sectors could result in an **unaffordable environmental burden** associated with **too high consumption** and **nutrient surpluses.**

- Action has to consider the **multidimensional, multidisciplinary and multiscale** nature of the challenge

- **N_2O emissions can be trigger if fertilization rates grow beyond certain** limits without efficient mitigation measures

THANKS TO MY COLLEAGUES!!

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Thank you very much

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