University of BRISTOL

INRA SCIENCE & IMPACT

ROTHAMSTED RESEARCH

European Federation of Animal Science

Dubrovnik, Croatia

September 2018

Sustainability metrics associated with product quality and land use.

M.R.F. Lee, T. Takahashi, G.A. McAuliffe, J.P. Domingues and M. Tichit

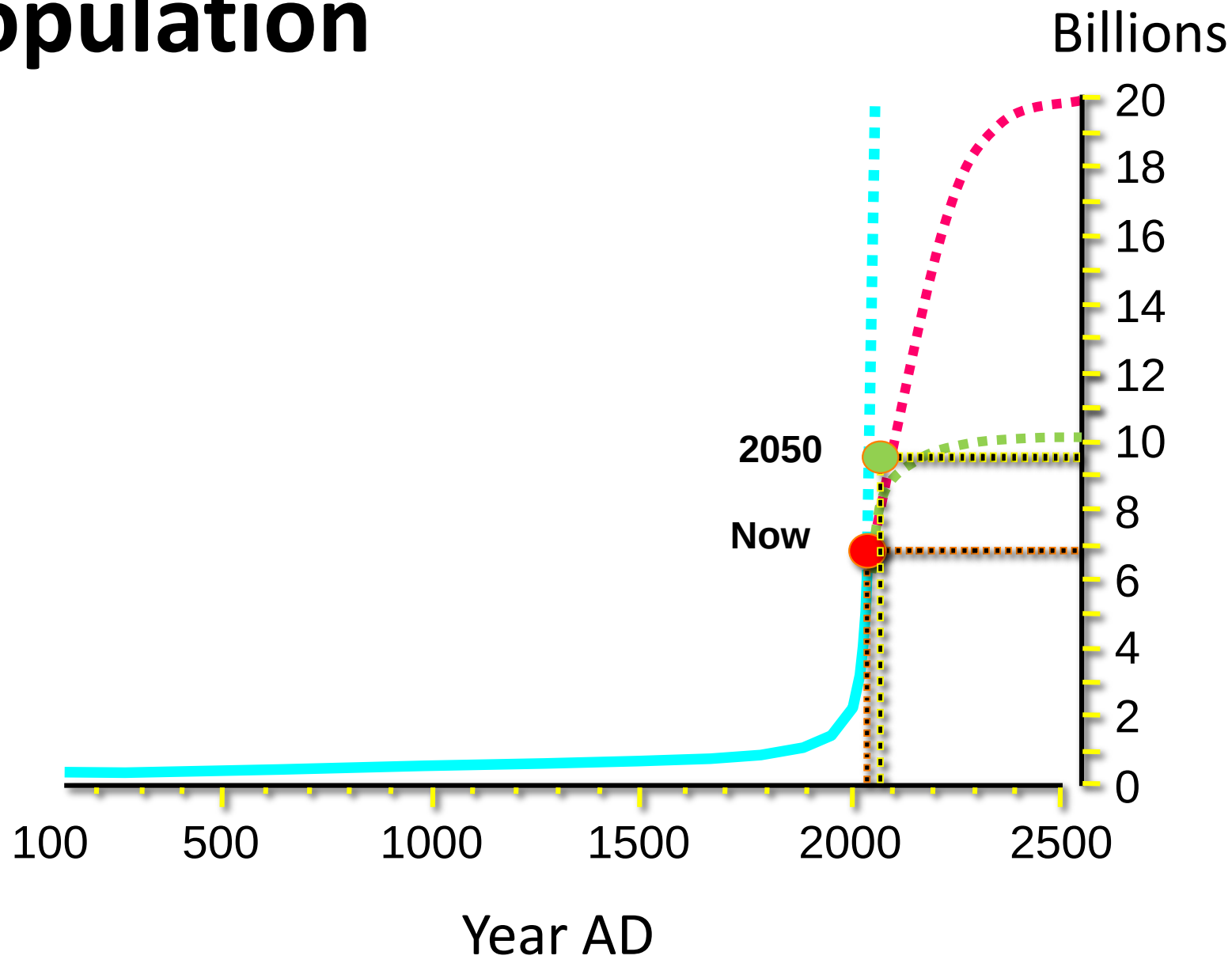
GLOBAL FARM PLATFORM

Towards Sustainable Ruminant Production

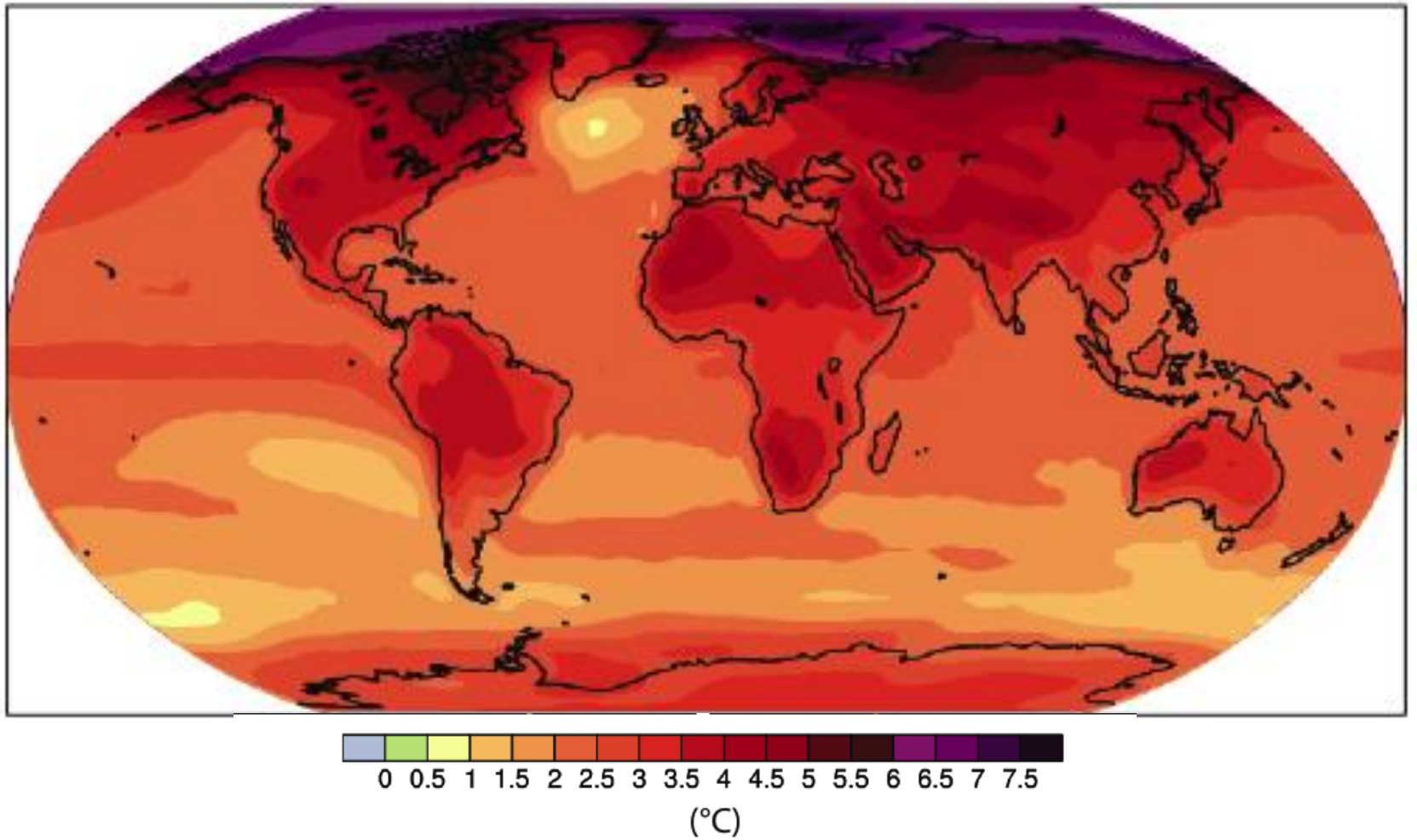
Global Challenges for Food Security

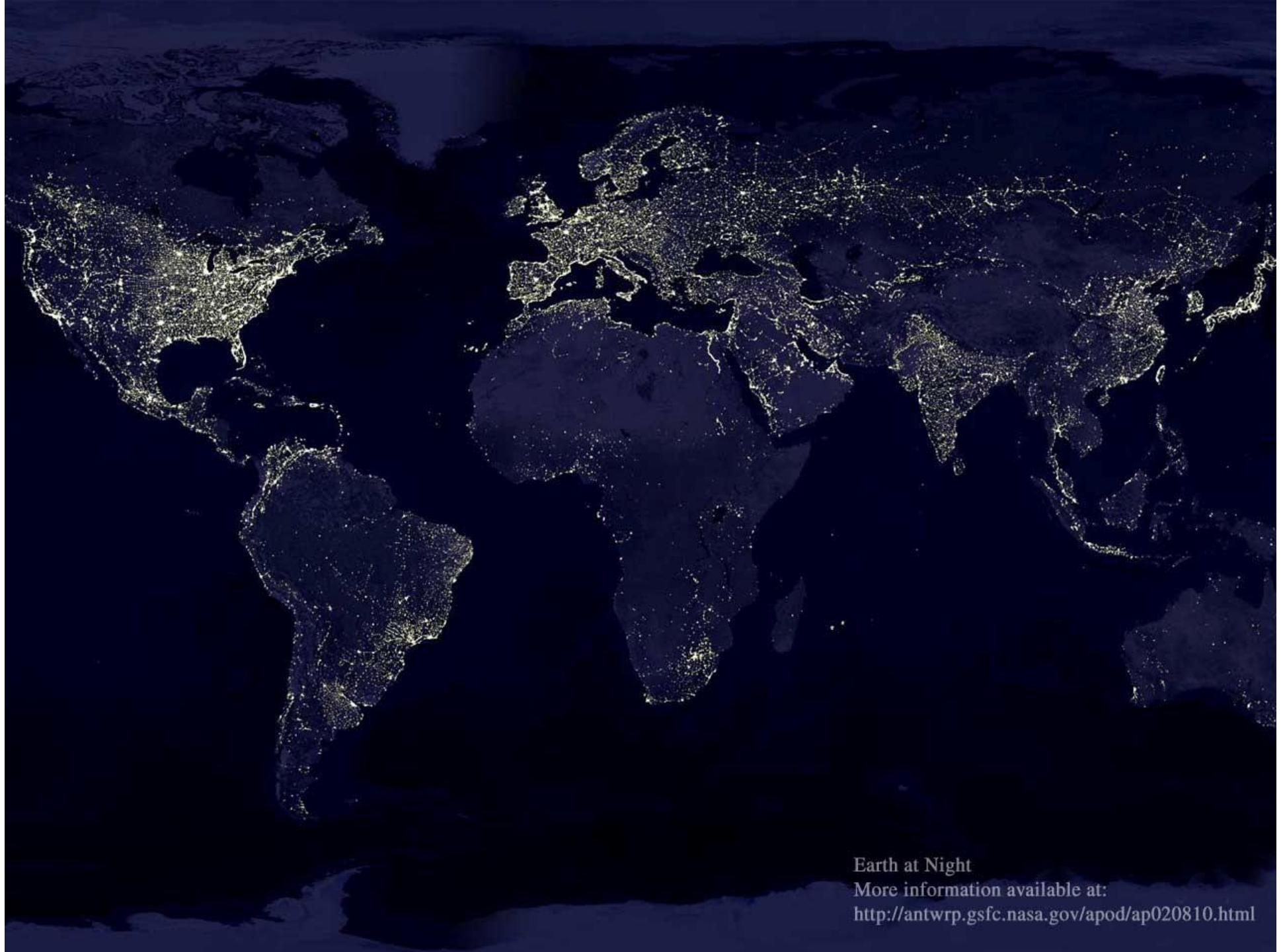
- Increasing population
- Increasing urbanisation
- Climate change
- Demand for animal protein

Population

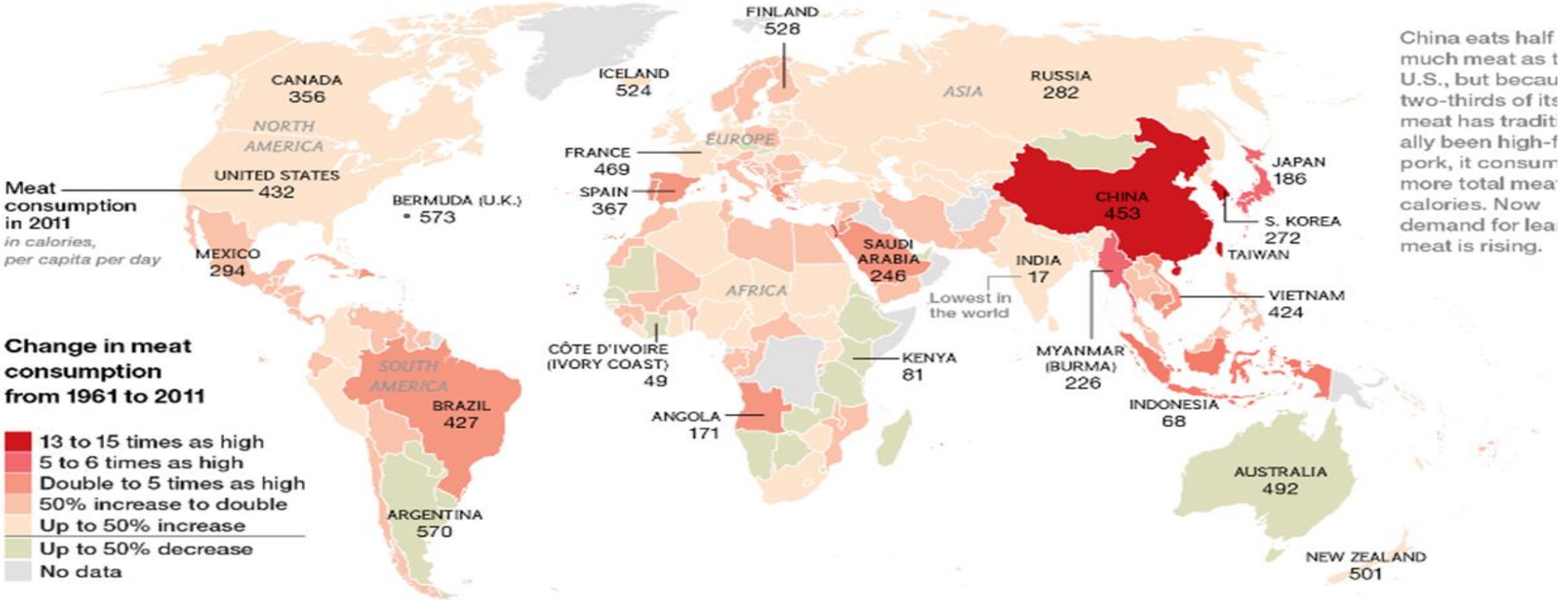

Billions
20
18
16
14
12
10
8
6
4
2
0
2050
Now
100
500
1000
1500
2000
2500
Year AD

Global mean warming 2.8°C
Much of land area warms by ≈3.5°C
Arctic warms by ≈7°C




Earth at Night
More information available at:
http://antwrp.gsfc.nasa.gov/apod/ap020810.html

Increasing Demand for Meat

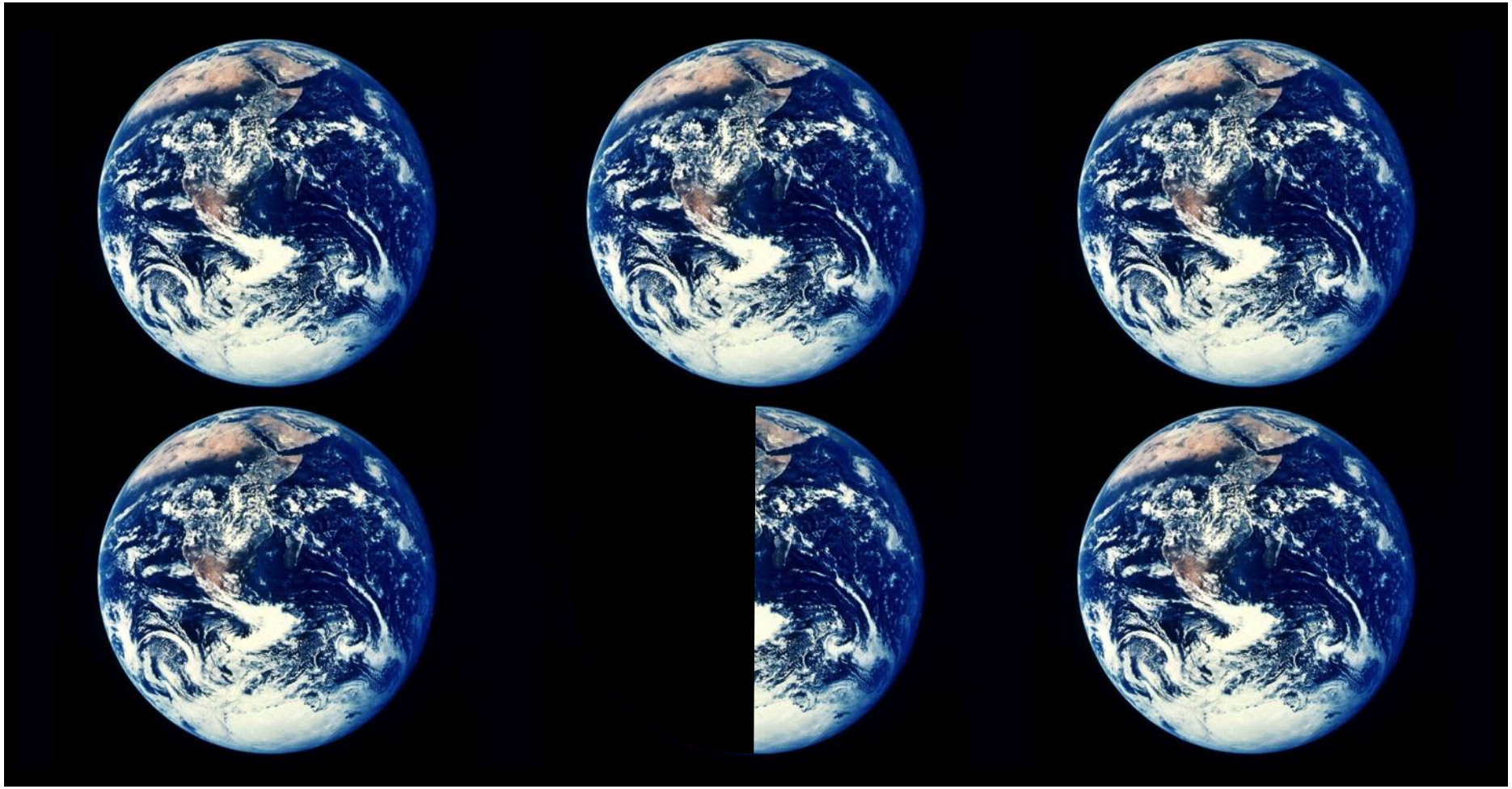


China eats half
much meat as t
U.S., but becau
two-thirds of its
meat has traditi
ally been high-f
pork, it consum
more total meat
calories. Now
demand for lea
meat is rising.

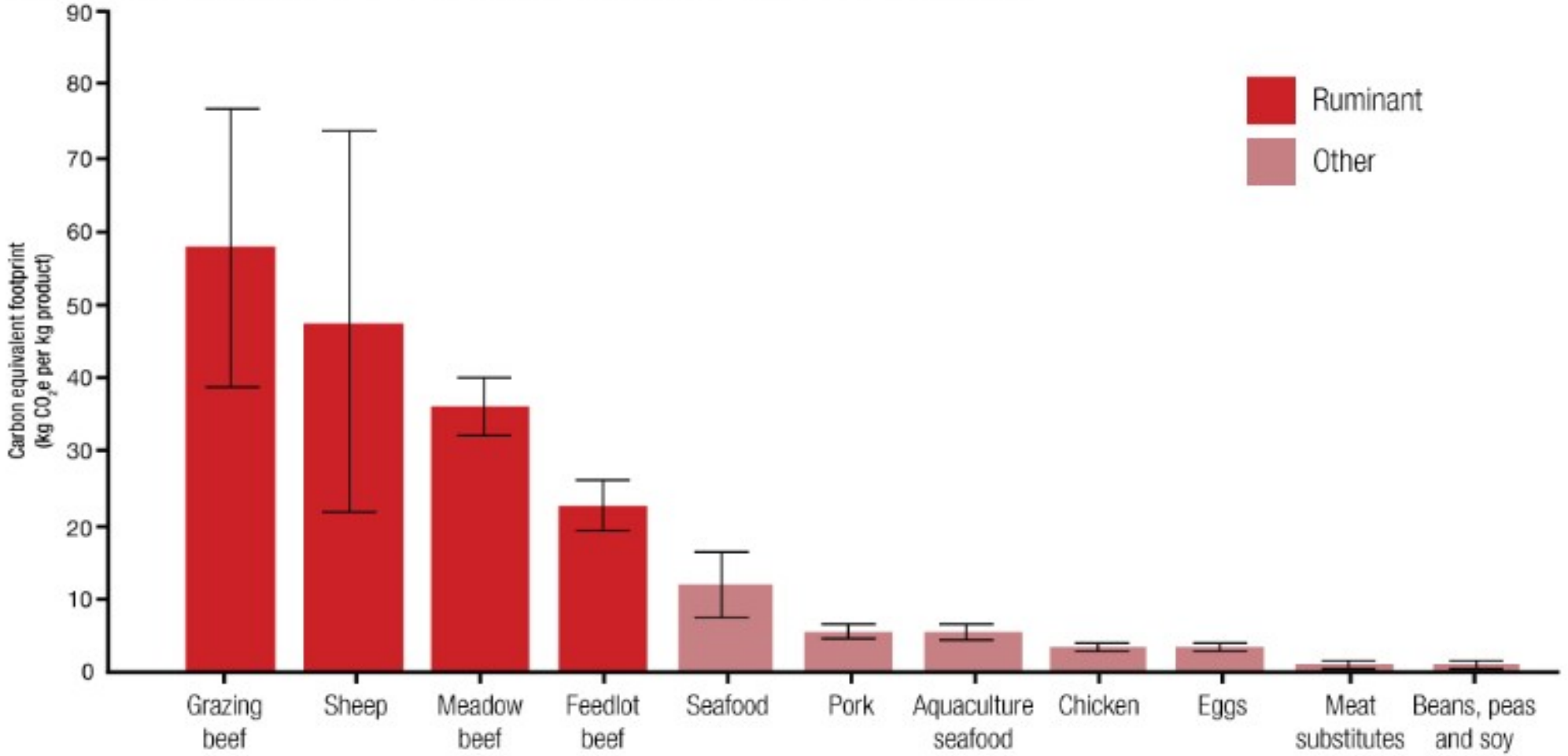
BBSRC bioscience for the future

NORTH WYKE ROTHAMSTED RESEARCH

Extra Planets?



Global Warming potential – mass based assessment (CO2eq/kg product)



Reproduced from Nature Climate Change: Ruminants, climate change and climate policy; January 2014

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NORTH WYKE ROTHAMSTED RESEARCH

Accounting for nutritional quality: e.g. omega-3

Most livestock LCA studies treat the end product (meat) as a homogenous good but...

Species	System	Study	Omega-3 (mg/100 g meat)	DHA + EPA (mg/100 g meat)	ω-6:ω-3
Beef	Concentrate	Warren et al.	20.3	3.4	14.4
	Forage	(2008a)	97.2	27.4	1.2
Chicken	Intensive	Givens et al.	362	17.6	5.5
	Free range	(2011)	214	14.7	7.6
Lamb	Lowland	Whittington et al.	94.0	26.4	1.2
	Upland	(2006)	103	31.7	1.5
Pork	Intensive	Enser et al. (1996)	51.3	14.8	7.4

Grass-based beef production systems produce meat that has:

- Higher omega-3 fats
- Lower omega-6:omega-3 ratios
- Higher levels of vitamin E

Accounting for nutritional quality: omega-3

Species	System	Mass-based GWP (kg CO_2-eq/kg meat)	Quality-based GWP (kg CO_2-eq/g omega-3)	Quality-based GWP (kg CO_2-eq/g DHA + EPA)
Beef	Concentrate	9.8	48.0	288.1
	Forage	18.3	18.5	67.7
Chicken	Intensive	4.4	1.2	25.1
	Free range	5.1	2.4	34.7
Lamb	Lowland	26.1	28.7	99.2
	Upland	30.9	30.0	98.9
Pork	Intensive	7.4	14.4	50.3

McAuliffe et al. (2018) *Food and Energy Security*

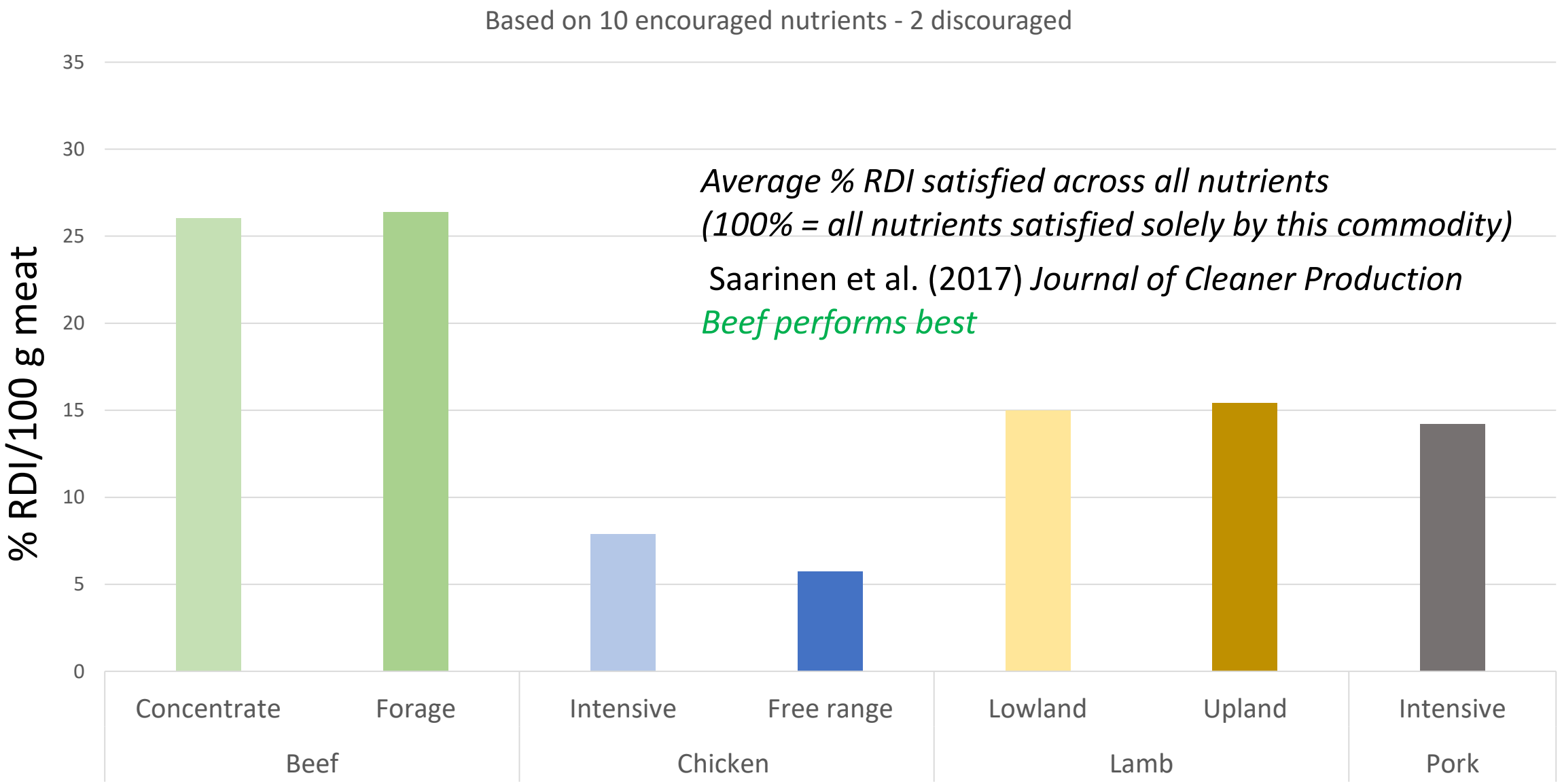
Accounting for nutritional quality: nutrient index (NI)

(contents per 100 g meat)

			Beef		Chicken		Lamb		Pork
Nutrient	Unit	RDI	Concentrate	Forage	Intensive	Free range	Lowland	Upland	Intensive
Protein	g	50.25	23.5	23.5	26.3	26.3	20	20	18.6
MUFA	g	37.5	1.13	1.63	3.70	5.44	1.30	1.07	0.85
EPA+DHA	mg	250	3.4	27.4	17.6	14.7	26.4	31.7	14.8
Ca	mg	700	5	5	11	11	12	12	10
Fe	mg	11.75	1.6	1.6	0.7	0.7	1.4	1.4	0.4
Riboflavin	mg	1.2	0.26	0.26	0.15	0.15	0.2	0.2	0.18
Folic acid	µg	200	16	16	9	9	6	6	1
Vitamin B12	µg	1.5	2	2	0	0	1	1	1
Se	µg	67.5	8	8	15	15	3	3	11
Zn	mg	8.25	4	4	1.5	1.5	2	2	1.3
Na	g	6	0.07	0.07	0.08	0.08	0.07	0.07	0.05
SFA	g	25	1.14	1.50	2.43	3.69	1.34	1.21	0. 90

Red: nutrients to be discouraged

Accounting for nutritional quality: nutrient index (NI)

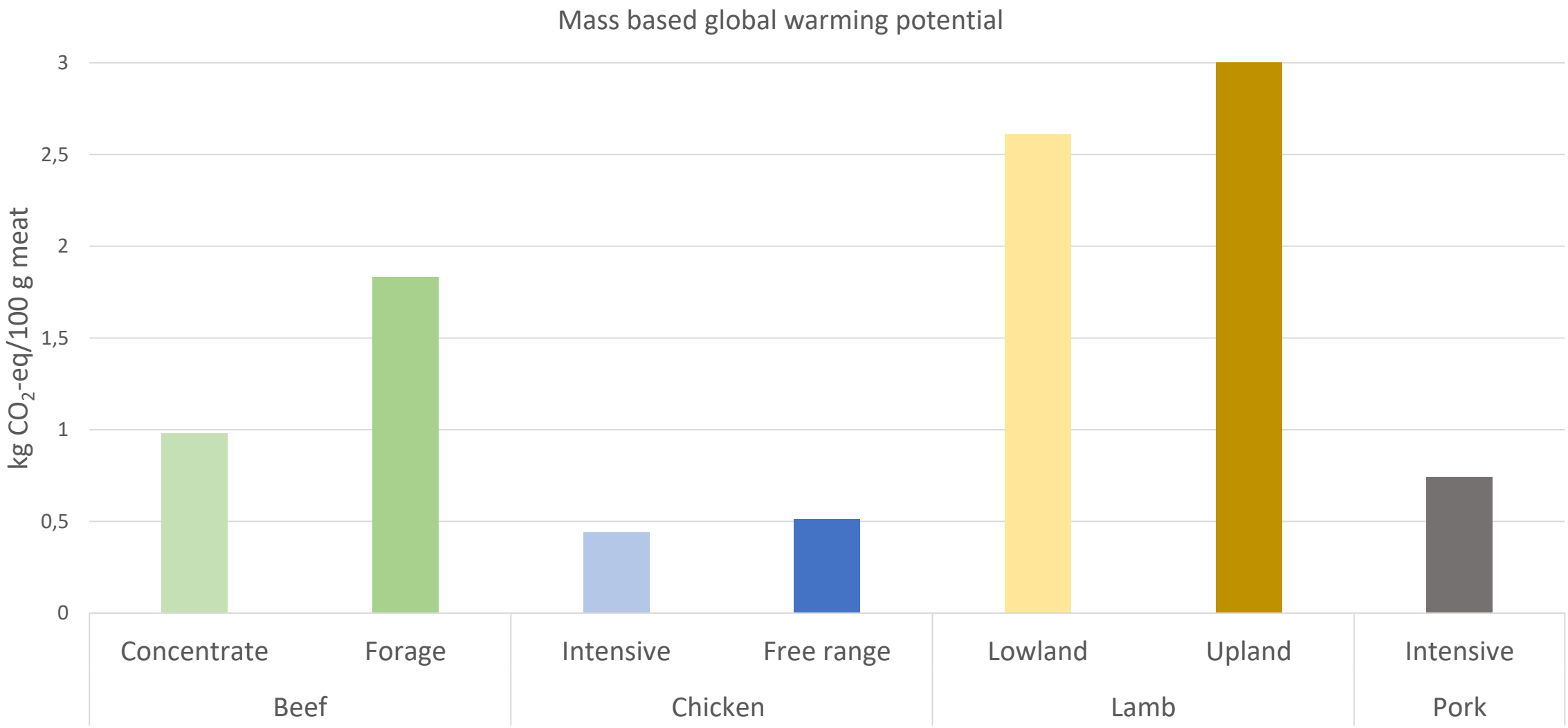


Average % RDI satisfied across all nutrients
(100% = all nutrients satisfied solely by this commodity)

Saarinen et al. (2017) *Journal of Cleaner Production*

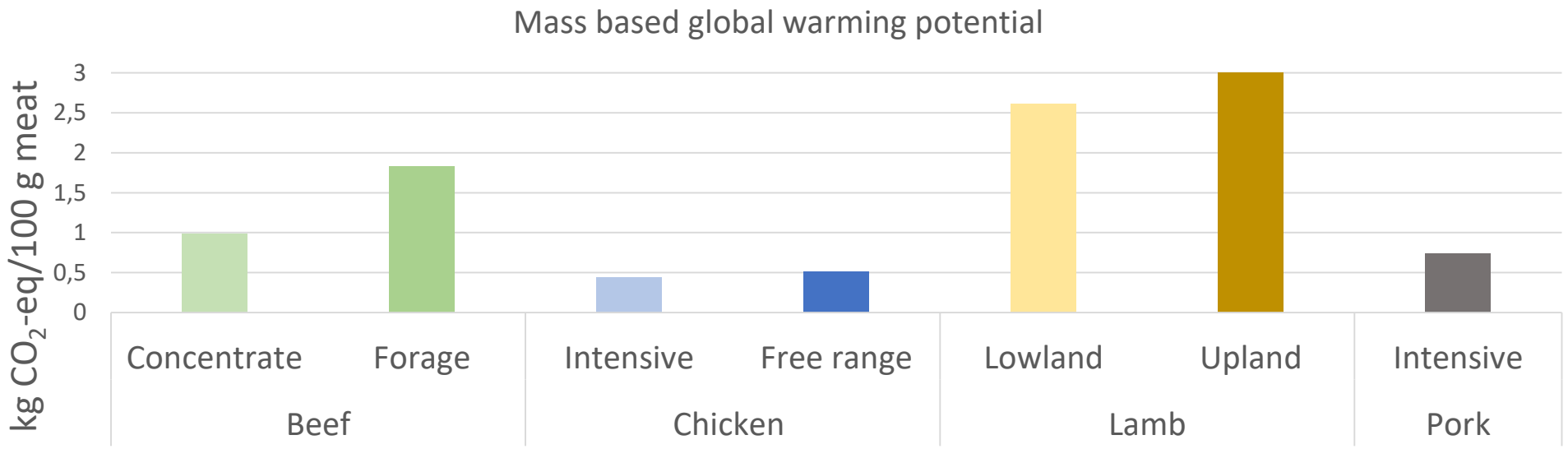
Beef performs best

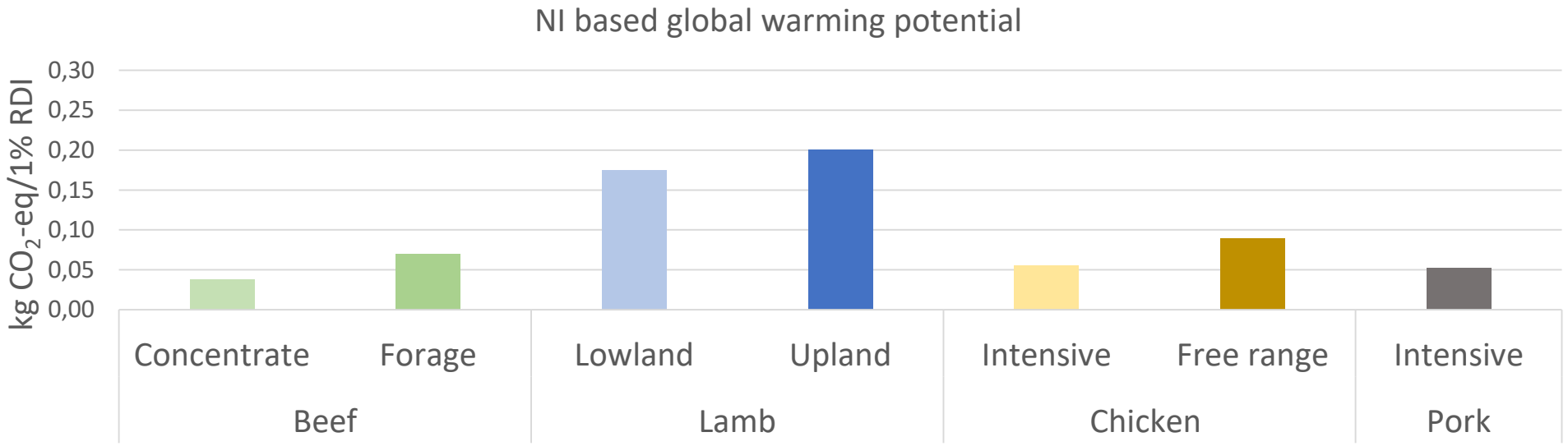
Baseline: conventional GWP (mass-based)



Chicken performs best

Mass-based GWP vs NI-based GWP

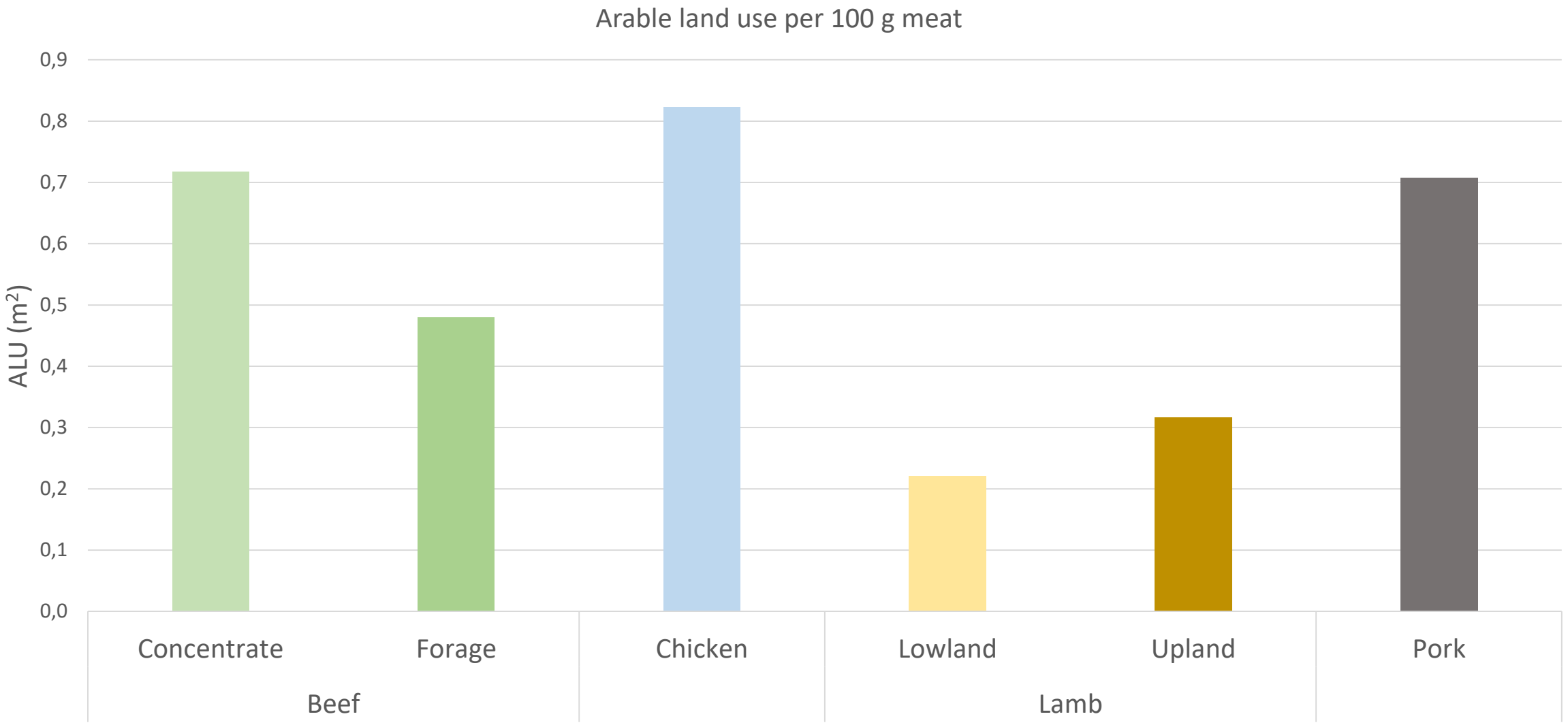




McAuliffe et al. (2018) *Food and Energy Security*

Beef performs best

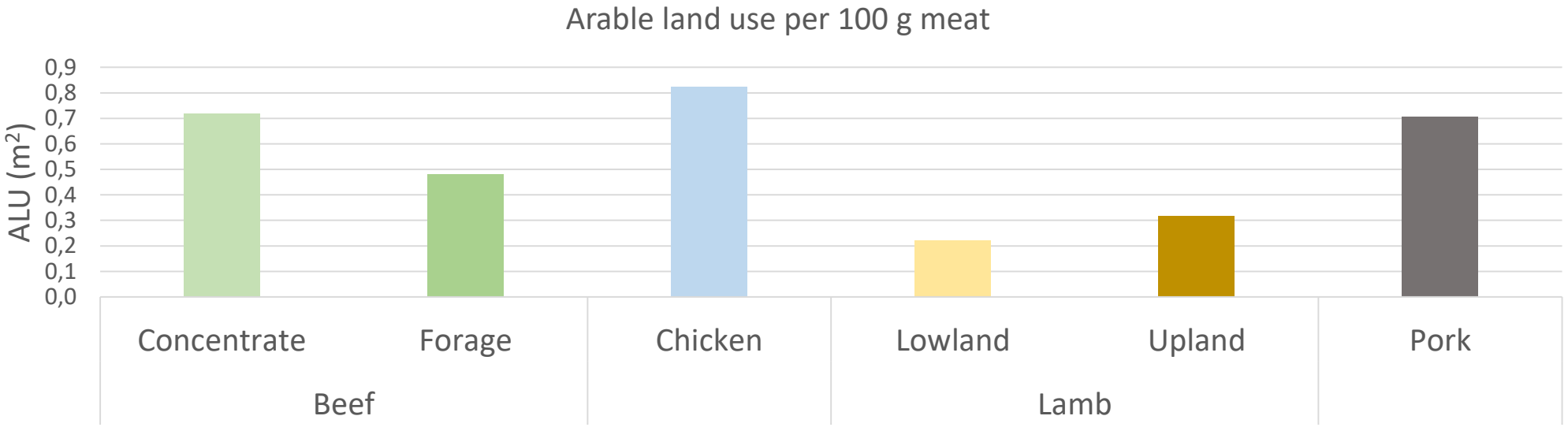
Accounting for other metrics: arable land use (ALU)

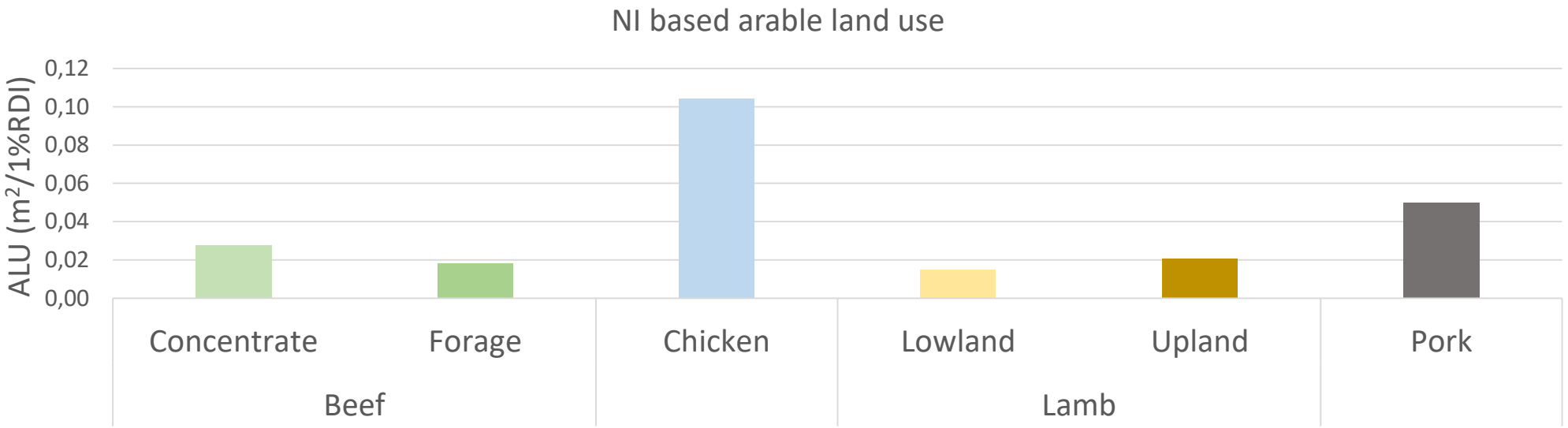


Lamb performs best

Wilkinson and Lee (2018) *animal*

Finally: Arable land use (ALU) per NI provision





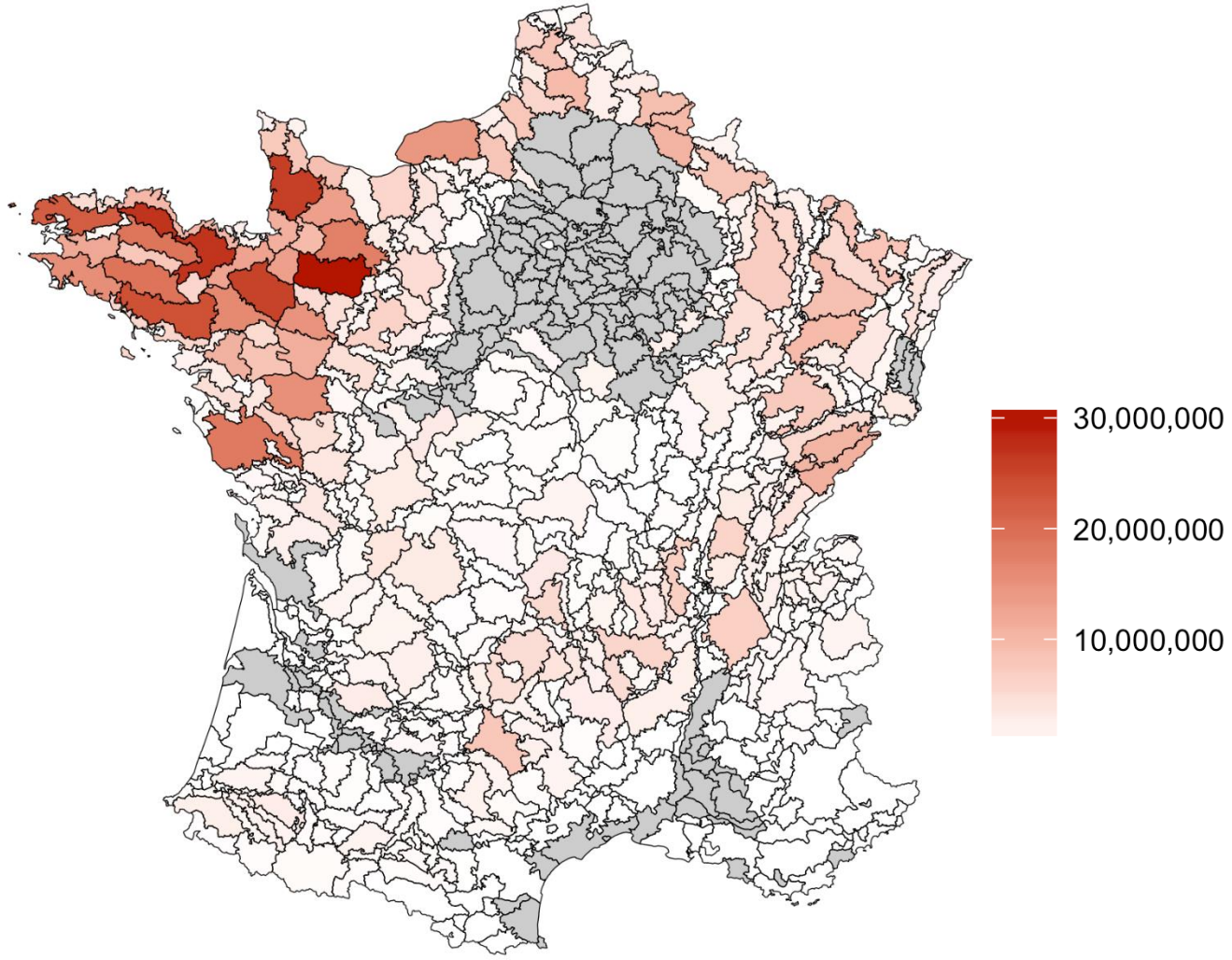
Lamb performs best

Upscaling the framework

- **Objective:** to test the hypothesis that ruminants can provide more nutrients for humans per ha of arable land than monogastrics
- **Case study:** INRA France 
- **Sample:** 571 agricultural land units (petites régions agricoles)

- Ruminant share: 0 – 1 based on livestock units
- NI: accounts for meat, milk and eggs
- GWP: based on life cycle assessment (LCA)
- ALU: includes displaced land outside PRA (Tichit et al., 16:45 today)

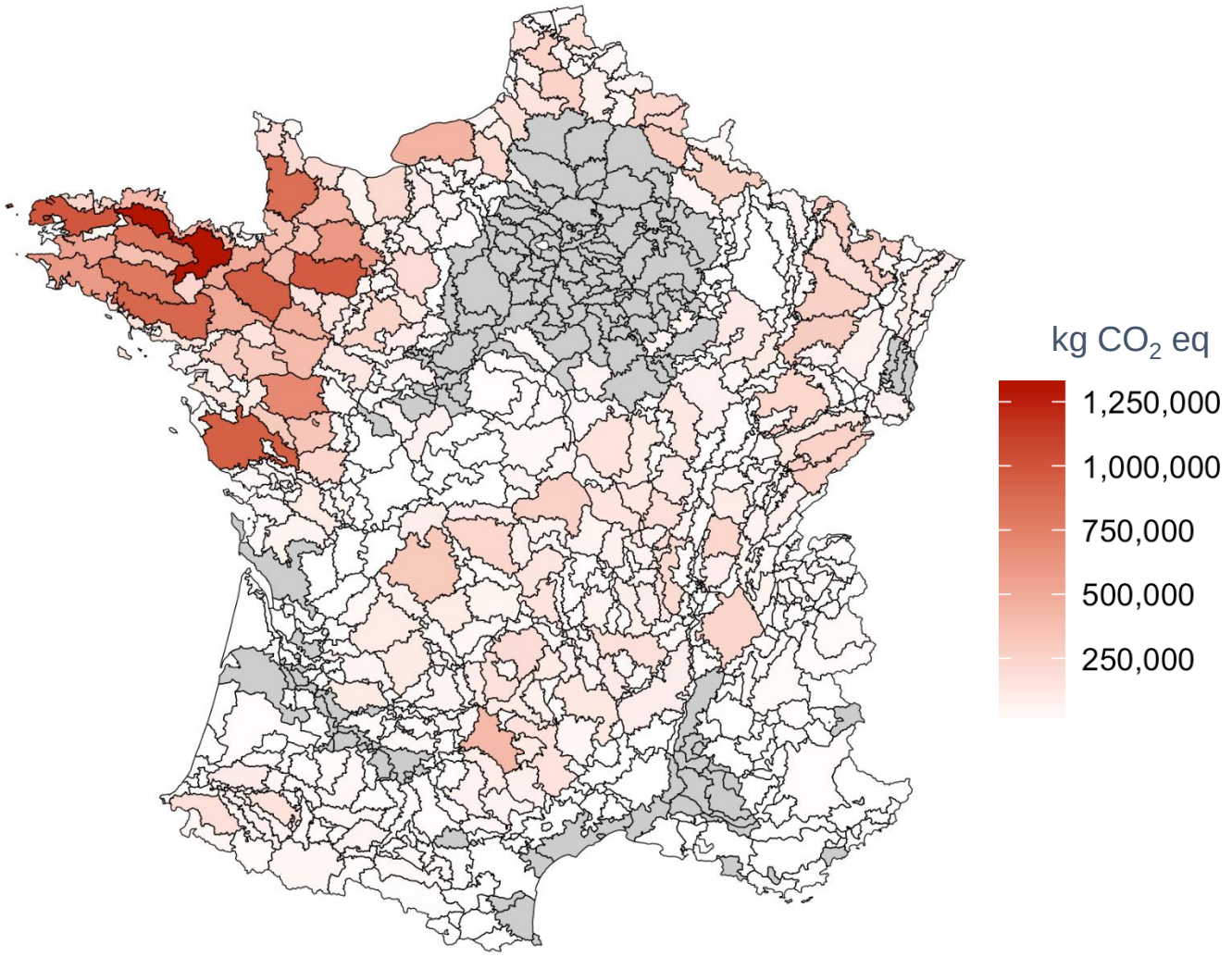
Nutrient Index



n = 571

Nutrient delivery per region from livestock (people/PRA)

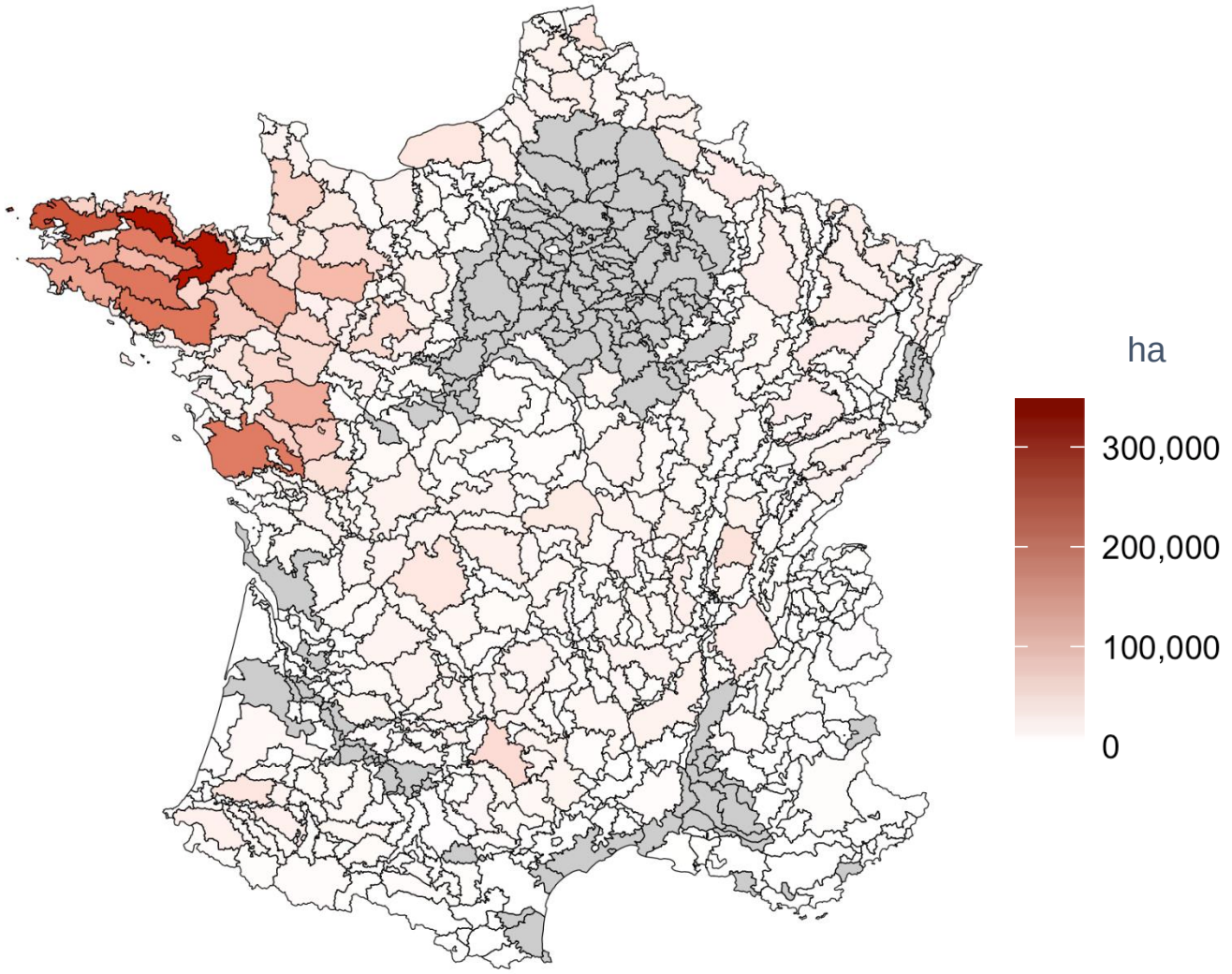
Global Warming Potential



n = 571

GWP from livestock (CO2eq/PRA)

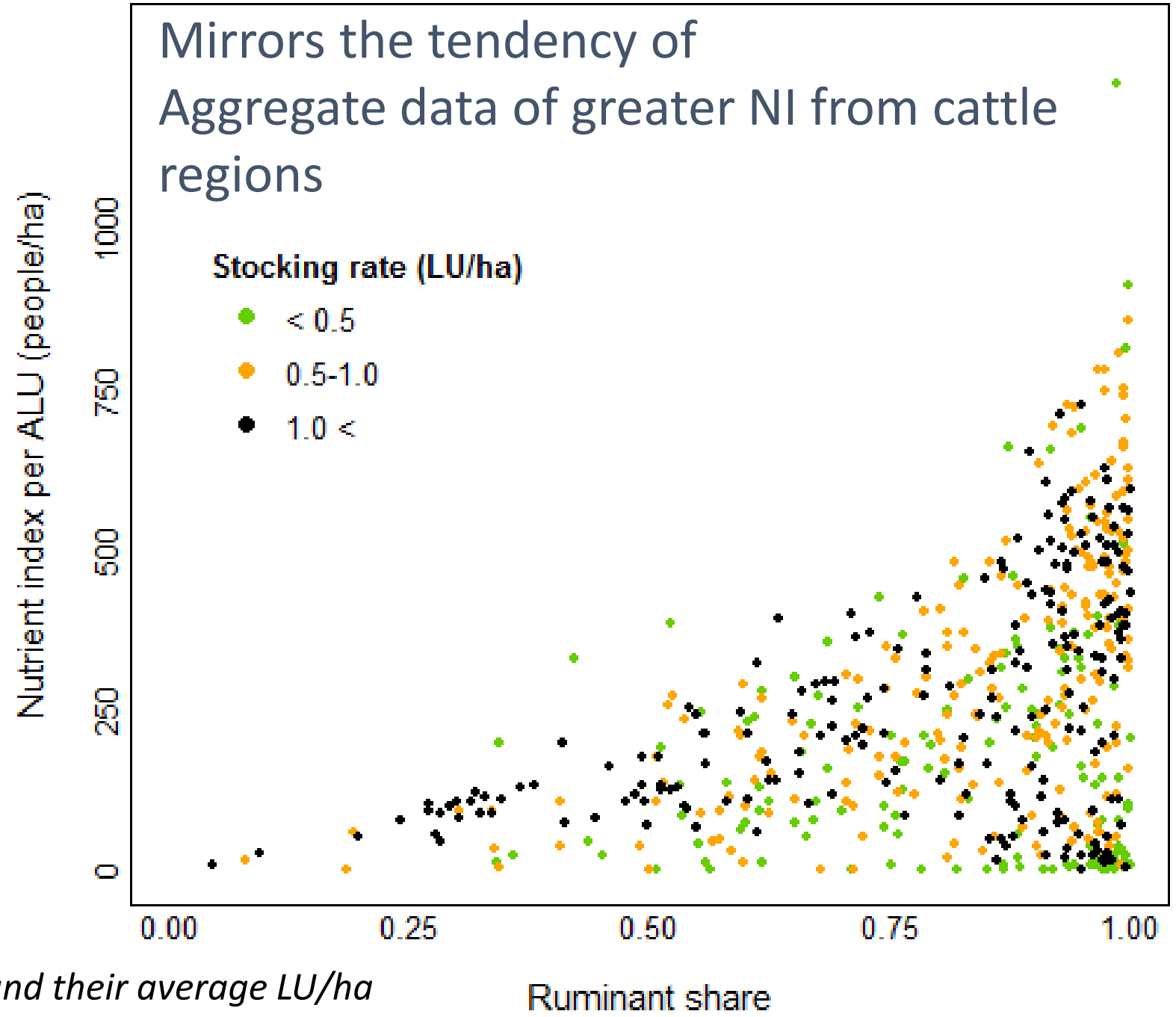
Arable Land Use for Livestock (including displacement)



n = 571

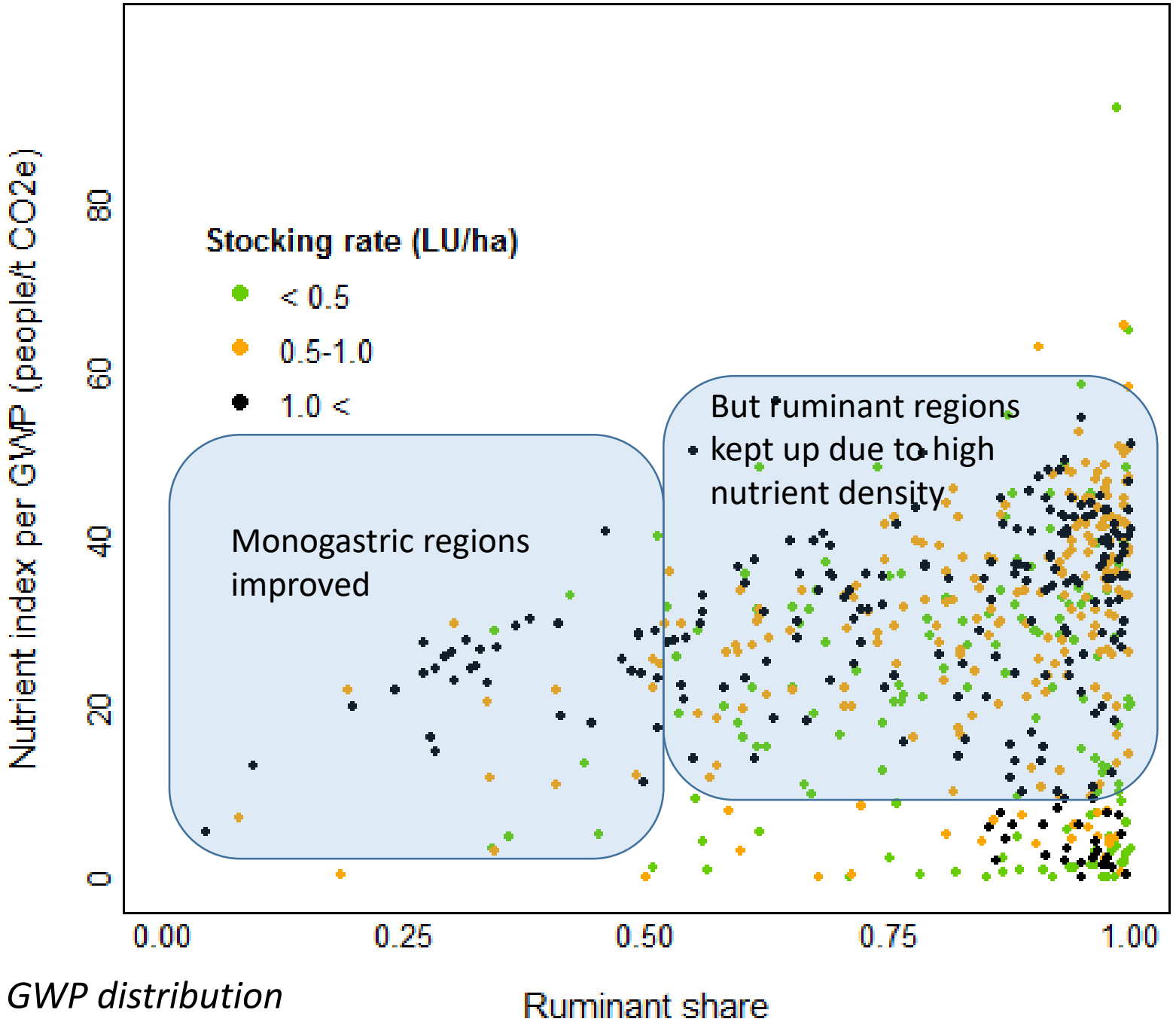
Arable land use for livestock including imports into region (ha/PRA)

NI per ALU



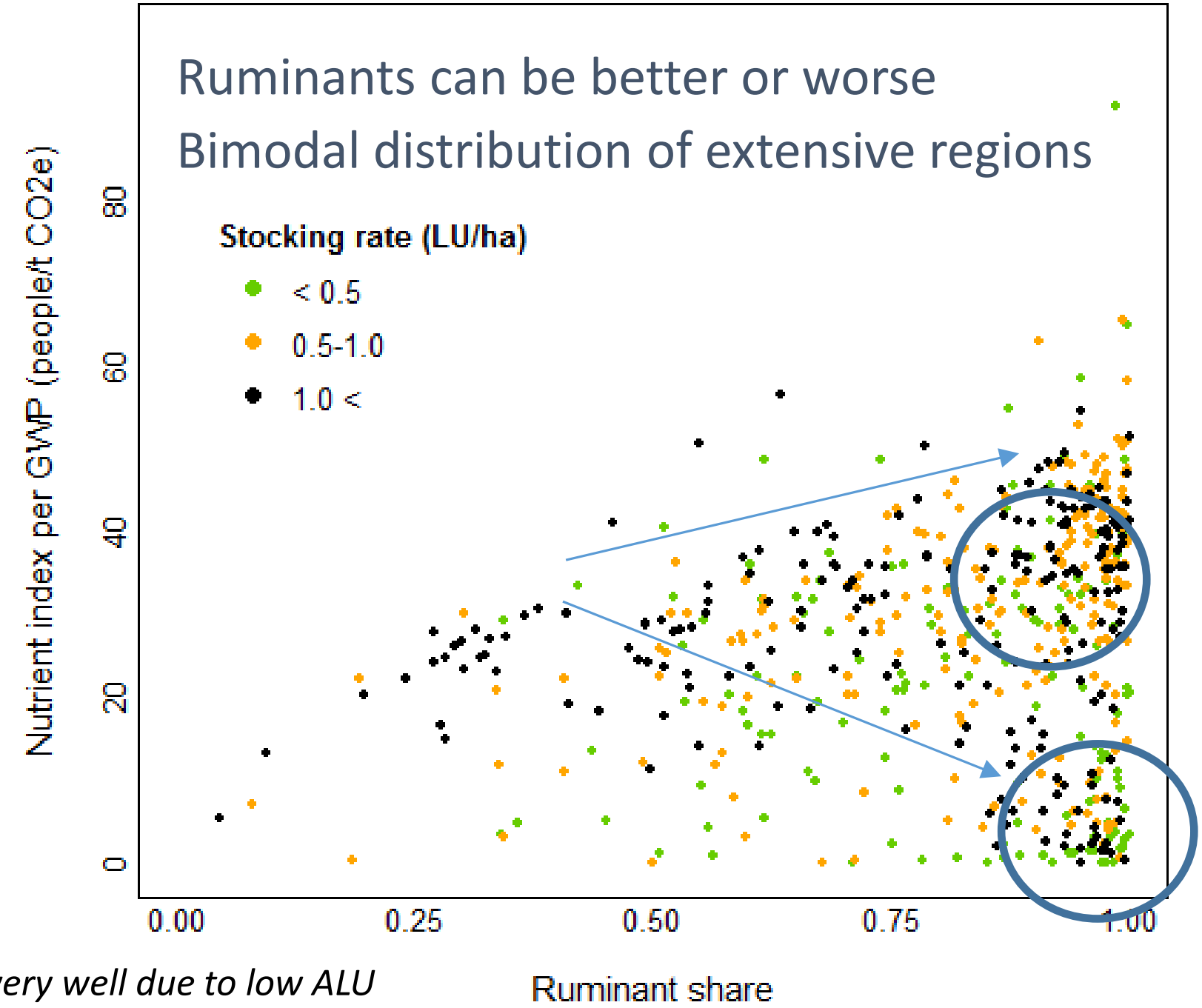
Each dot represents a PRA and their average LU/ha

NI per GWP



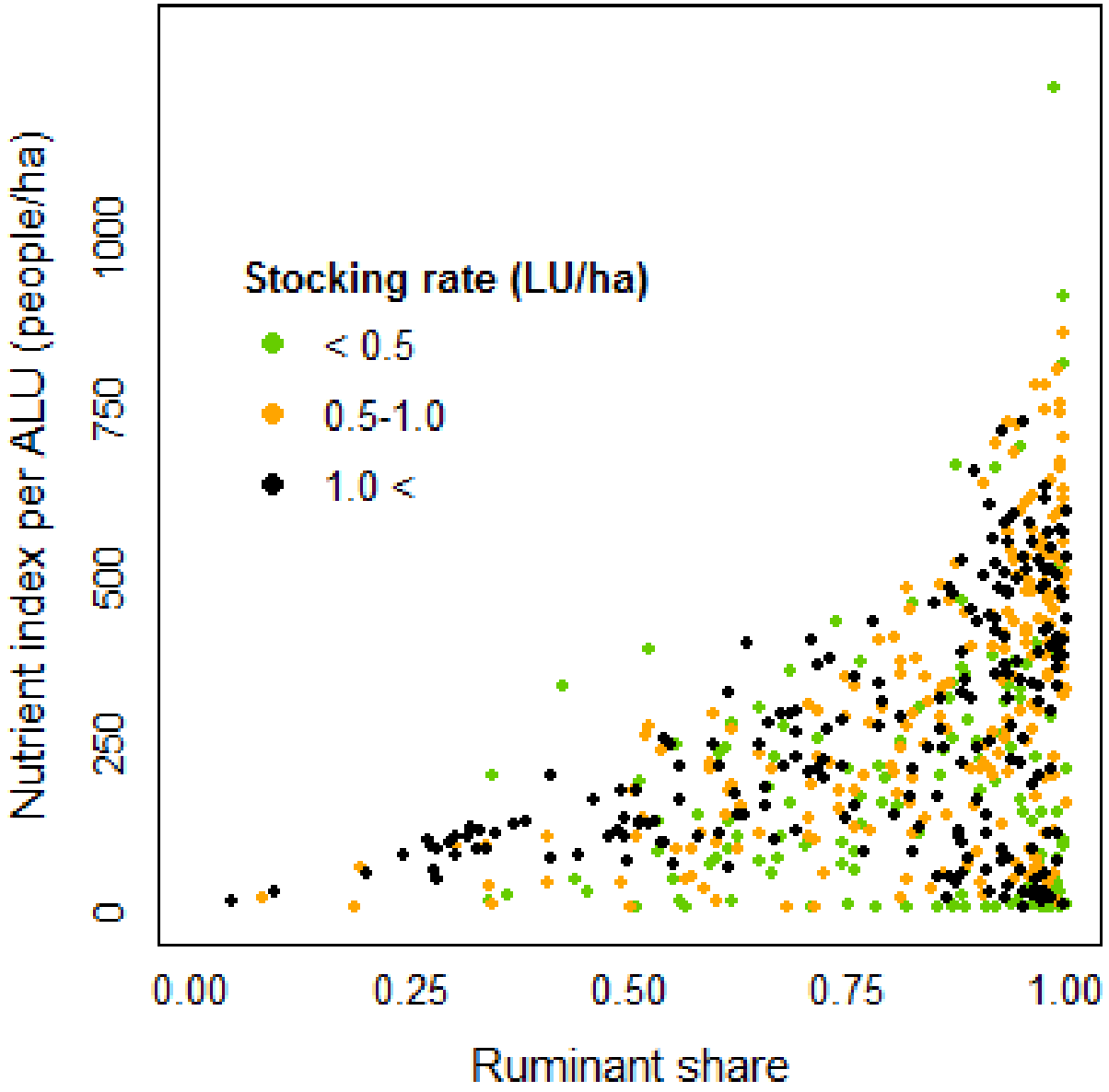
High nutrient density affects GWP distribution

NI per GWP

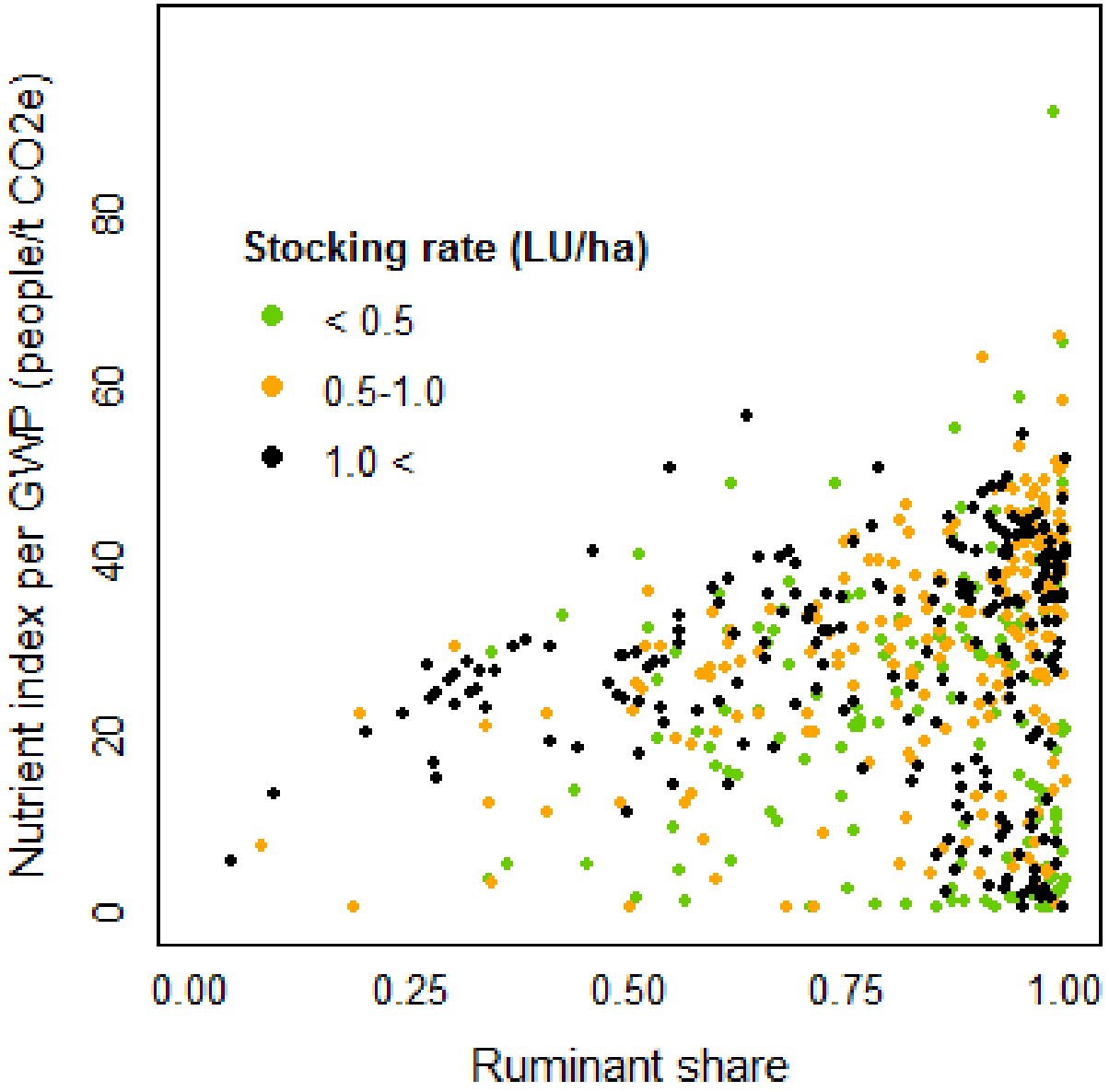


Extensive regions can perform very well due to low ALU

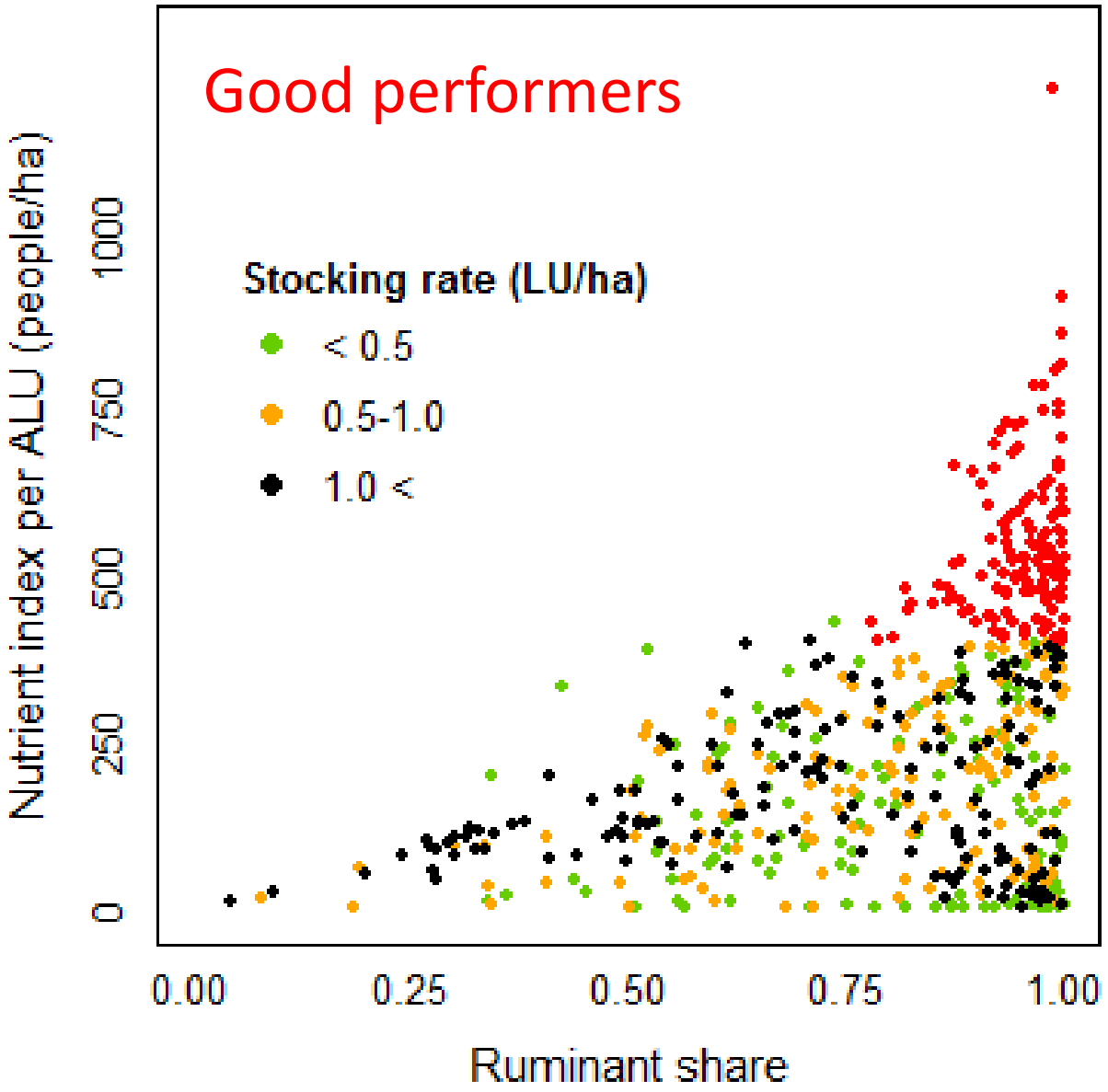
NI per ALU



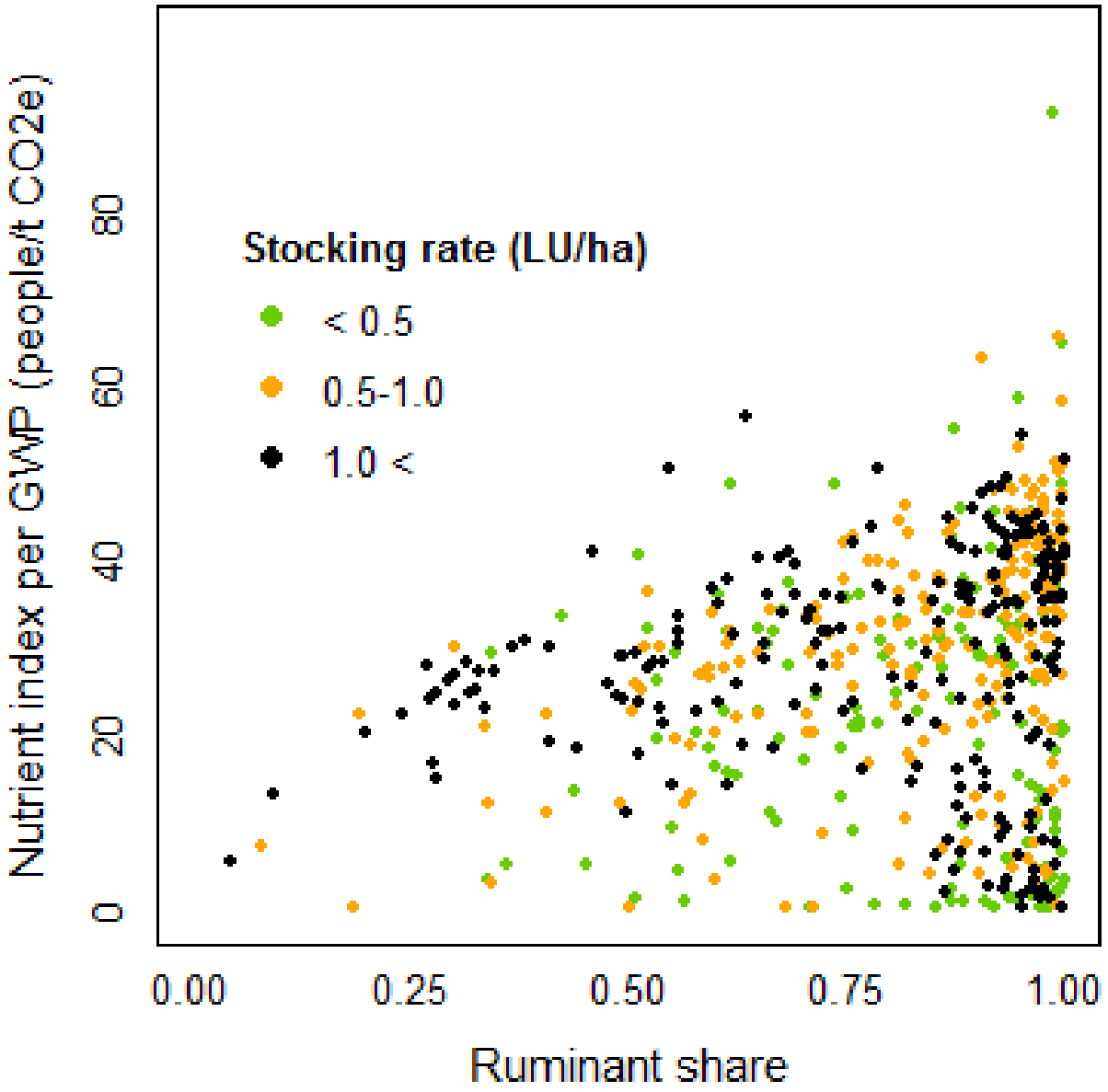
NI per GWP



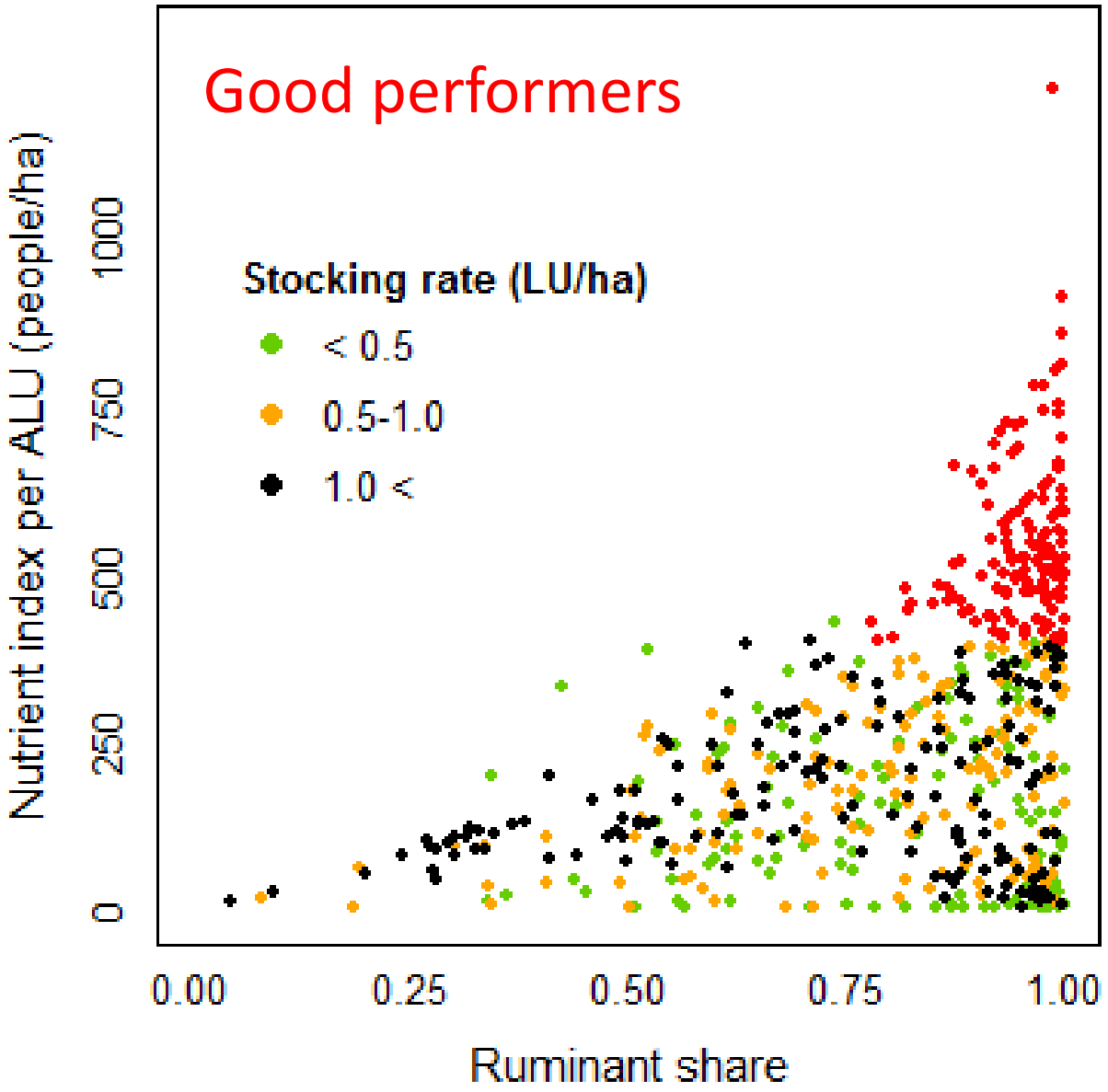
NI per ALU



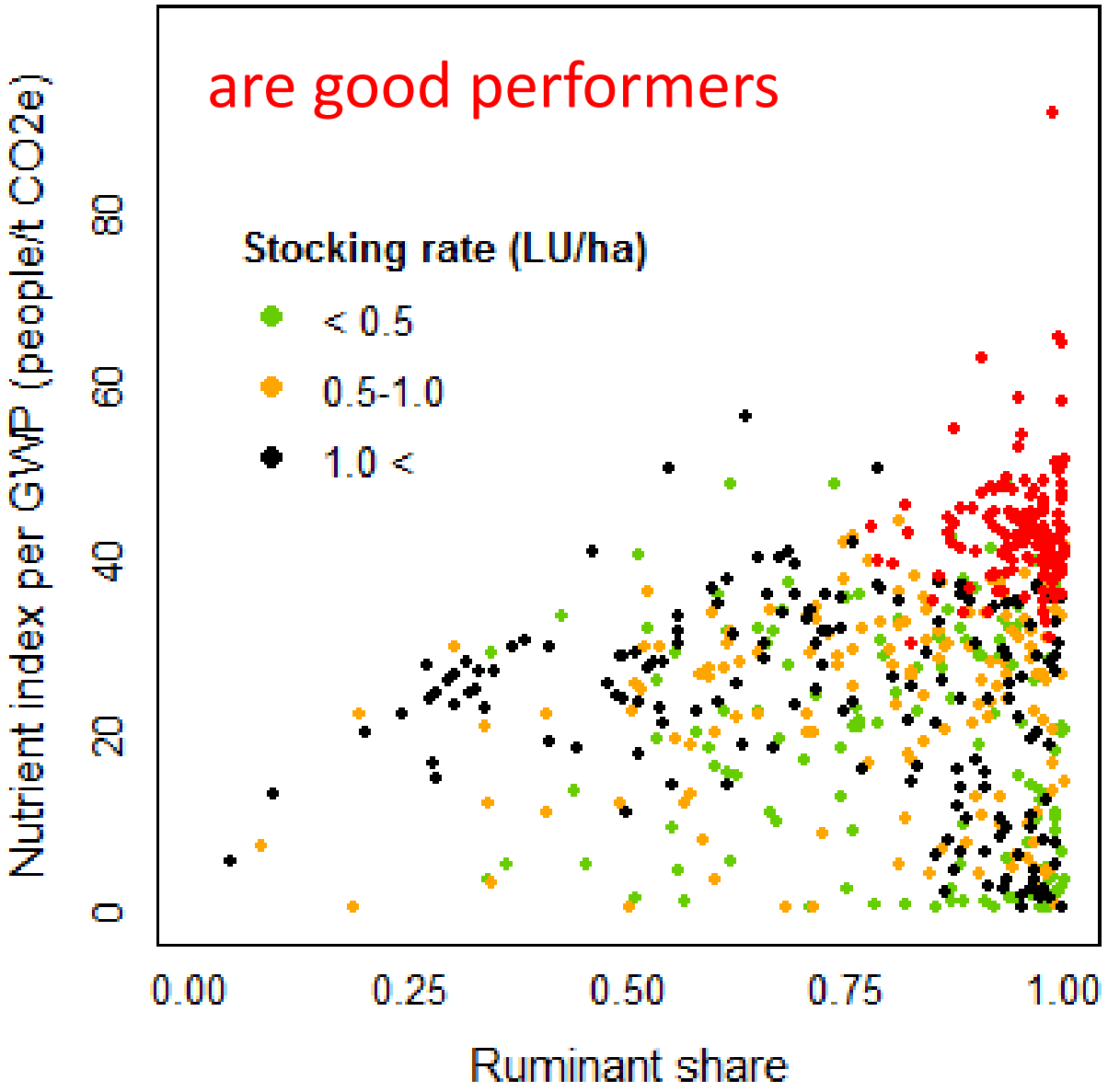
NI per GWP



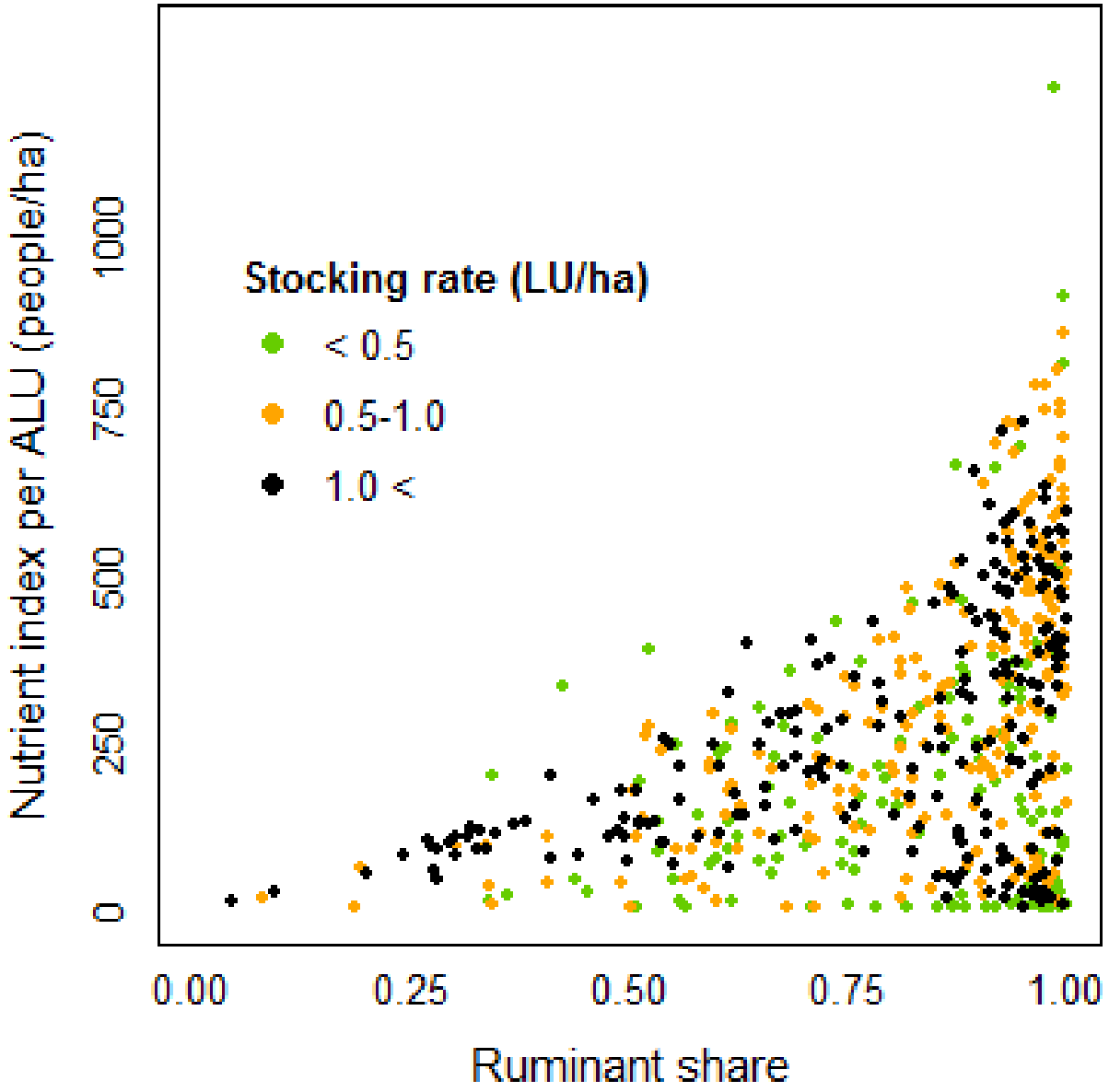
NI per ALU



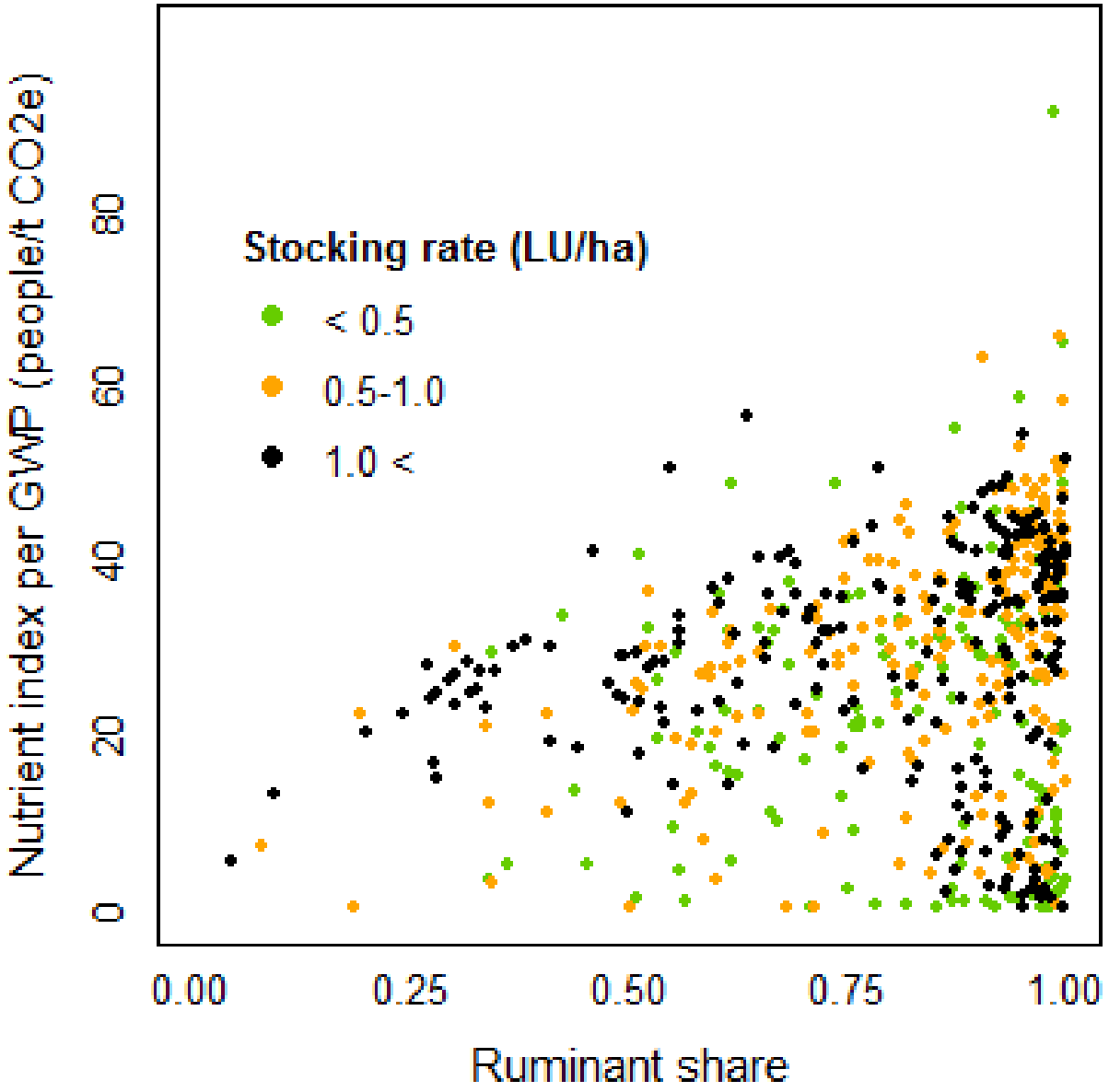
NI per GWP



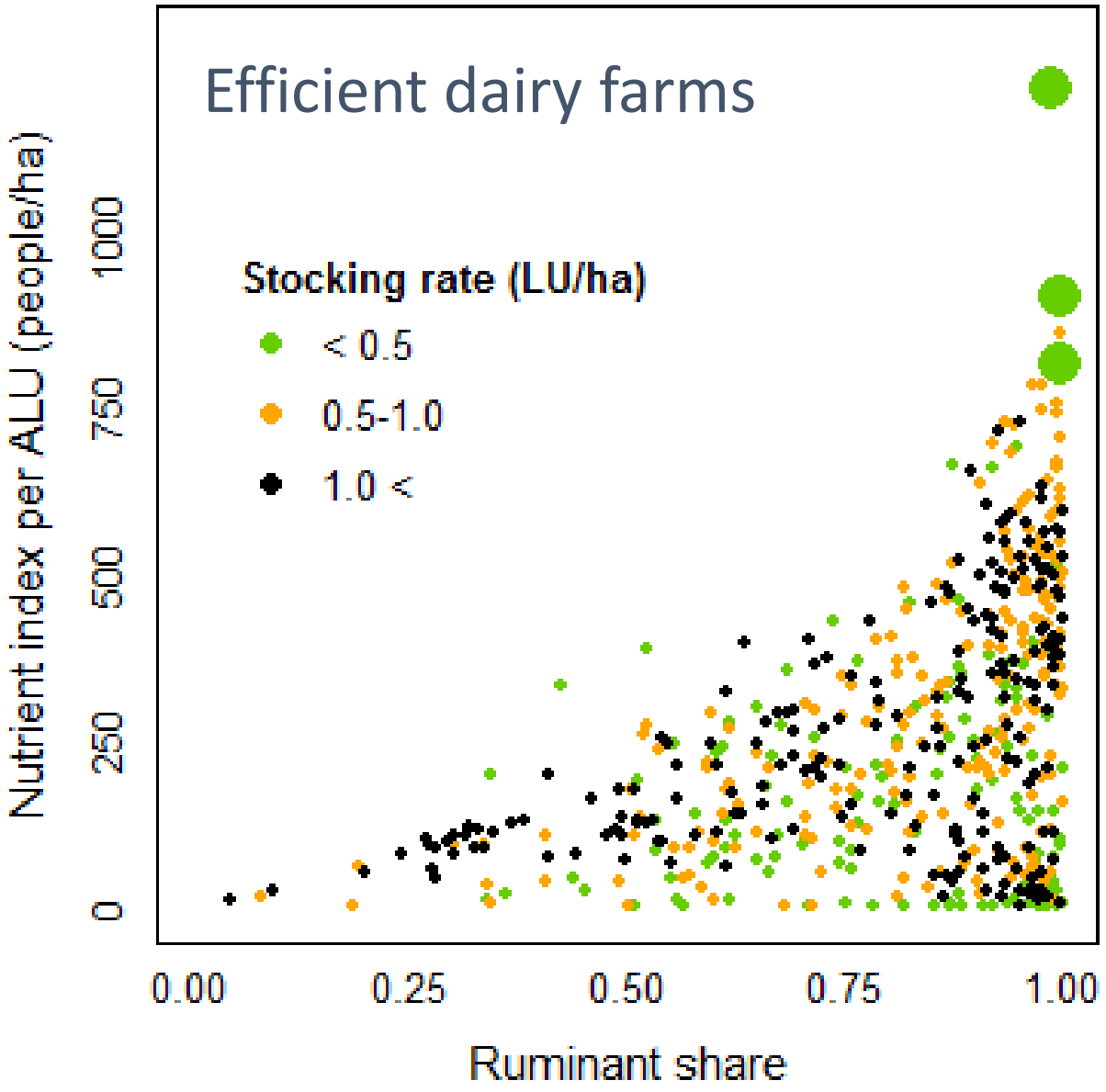
NI per ALU



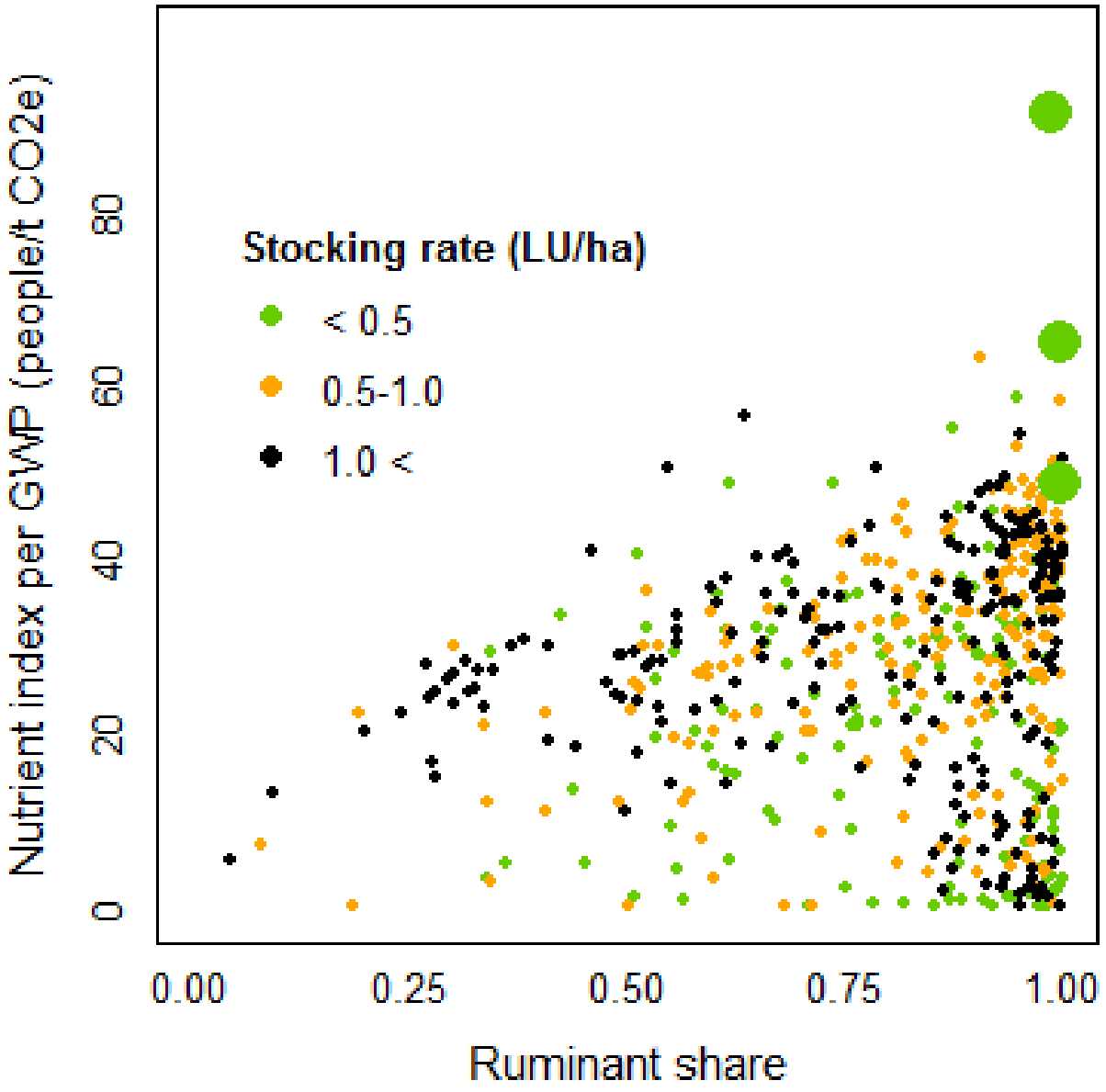
NI per GWP



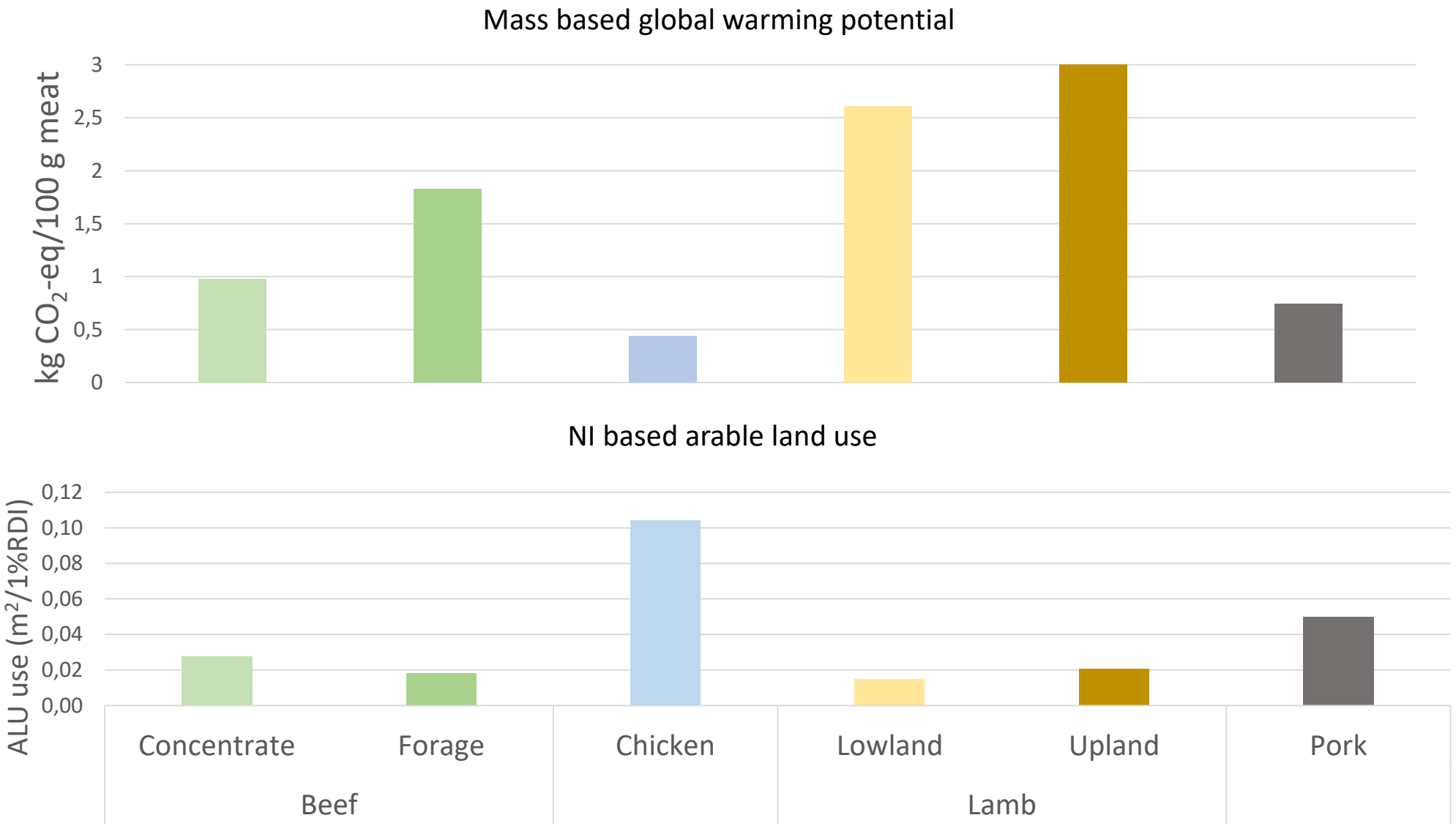
NI per ALU



NI per GWP



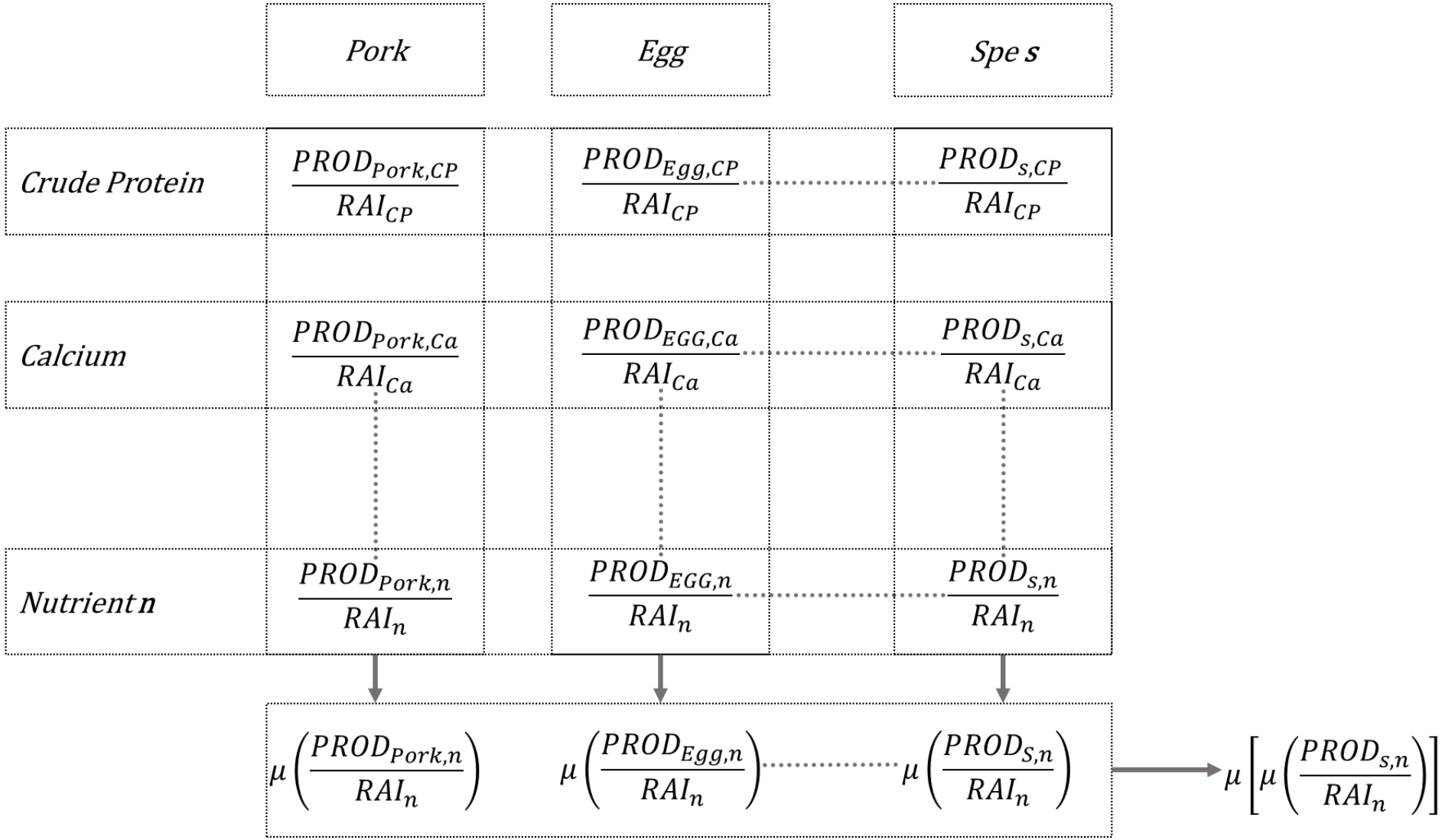
What is sustainability?



Livestock of course are more than food

Livestock are part of the solution for sustainable global food security

But great care must be given in developing metrics when determining their role


Pork
Egg
Spe s
Crude Protein
Calcium
Nutrient n
$\frac{PROD_{Pork,CP}}{RAI_{CP}}$
$\frac{PROD_{Egg,CP}}{RAI_{CP}}$
$\frac{PROD_{s,CP}}{RAI_{CP}}$
$\frac{PROD_{Pork,Ca}}{RAI_{Ca}}$
$\frac{PROD_{EGG,Ca}}{RAI_{Ca}}$
$\frac{PROD_{s,Ca}}{RAI_{Ca}}$
$\frac{PROD_{Pork,n}}{RAI_{n}}$
$\frac{PROD_{EGG,n}}{RAI_{n}}$
$\frac{PROD_{s,n}}{RAI_{n}}$
$\mu\left(\frac{PROD_{Pork,n}}{RAI_{n}}\right)$
$\mu\left(\frac{PROD_{Egg,n}}{RAI_{n}}\right)$
$\mu\left(\frac{PROD_{S,n}}{RAI_{n}}\right)$
$\mu\left[\mu\left(\frac{PROD_{s,n}}{RAI_{n}}\right)\right]$