FUTURE OF AGRICULTURE IN A FAST-CHANGING SOCIETY

CULTURELE KRING, OISTERWIJK

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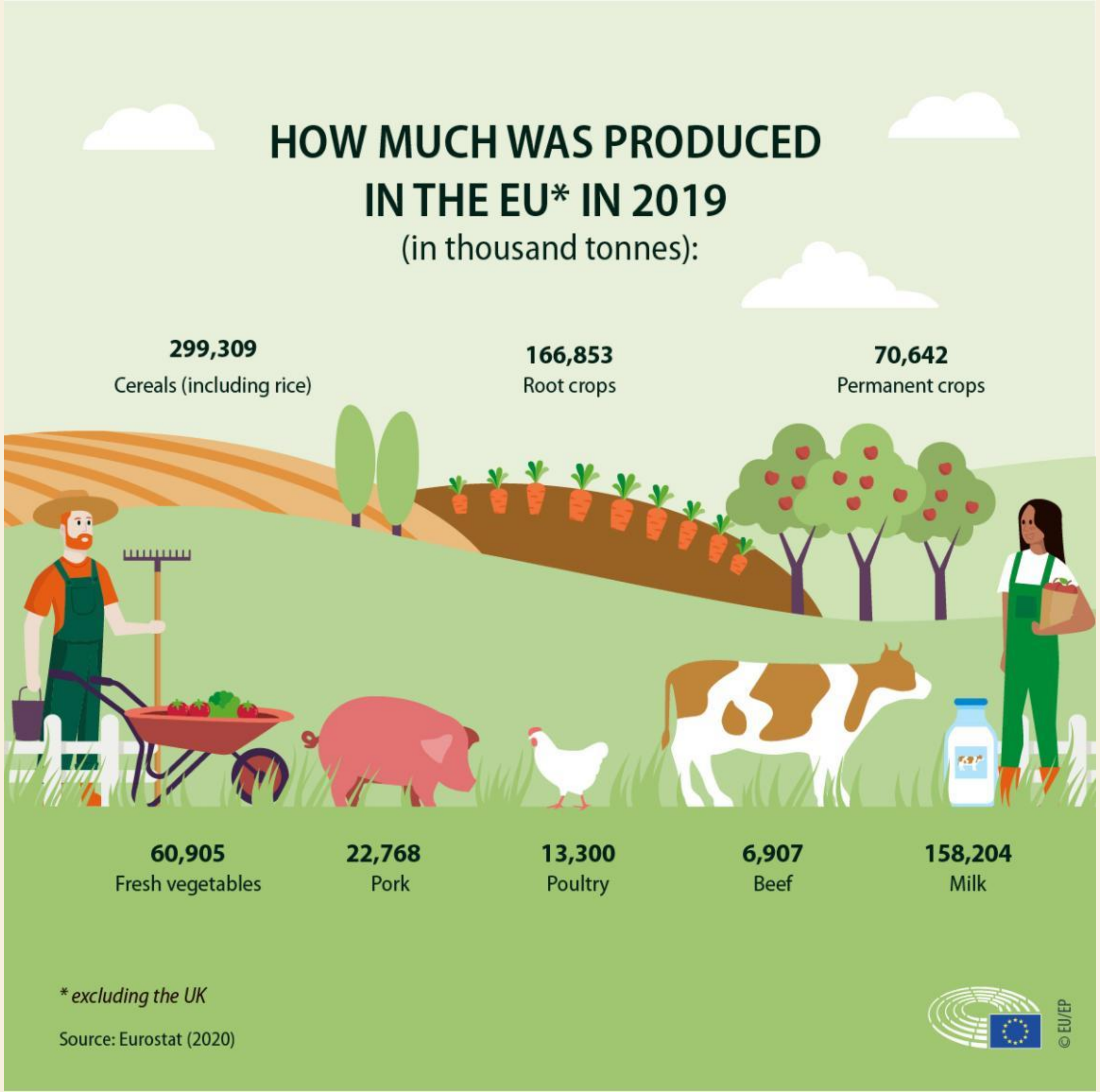
OUTLINE

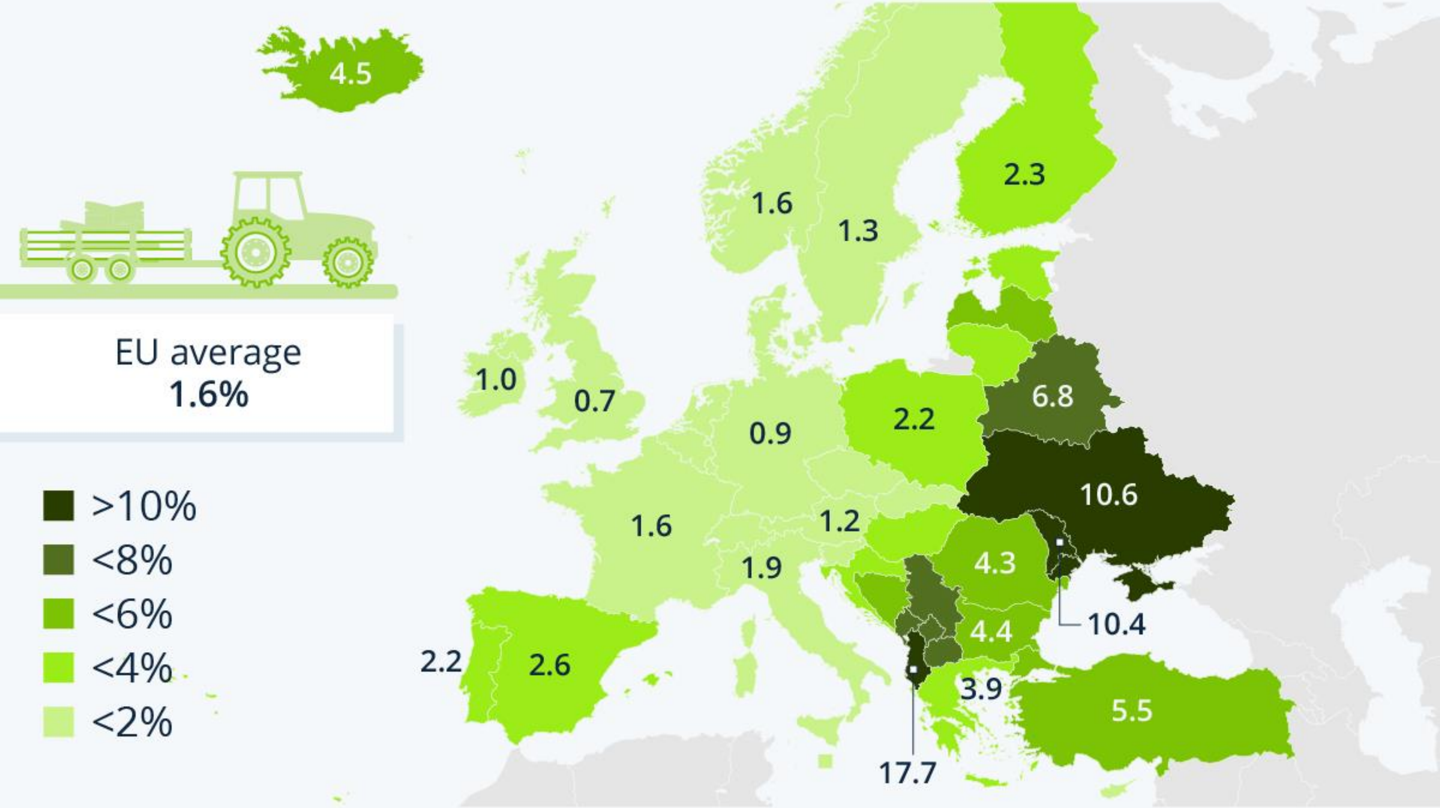
- Facts and Figures
- Climate Change and Agriculture
- GM and Biodiversity
- Nitrogen and Water Crisis
- Danish Model: The Organic Way
- CAP Post-2027 Proposal
- Future Challenges and Opportunities

FACTS AND FIGURES

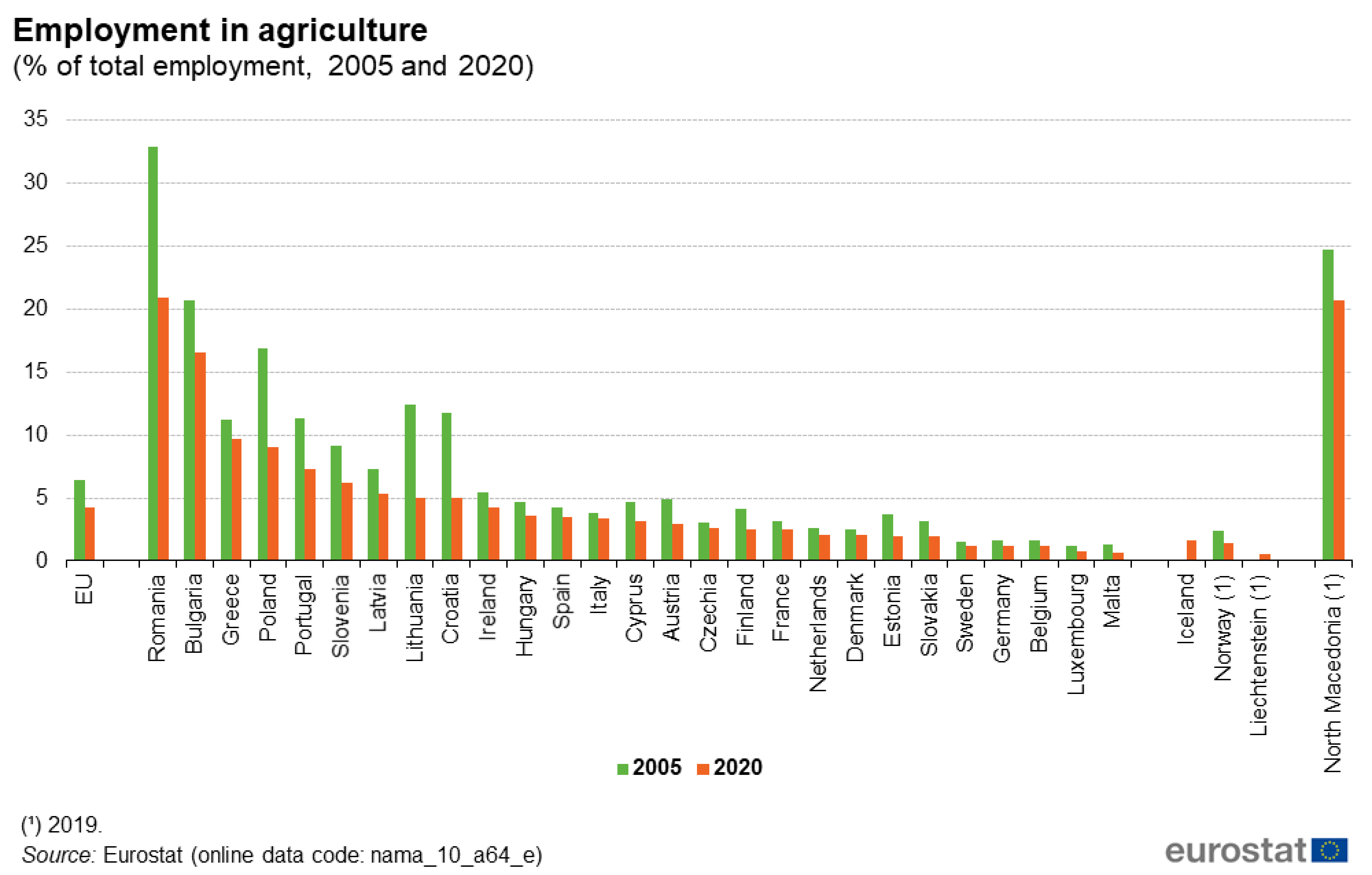

HOW MUCH WAS PRODUCED
IN THE EU* IN 2019
(in thousand tonnes):
299,309
Cereals (including rice)
166,853
Root crops
70,642
Permanent crops
60,905
Fresh vegetables
22,768
Pork
13,300
Poultry
6,907
Beef
158,204
Milk
* excluding the UK
Source: Eurostat (2020)
© EU/EP

The Value of Agriculture to European Economies

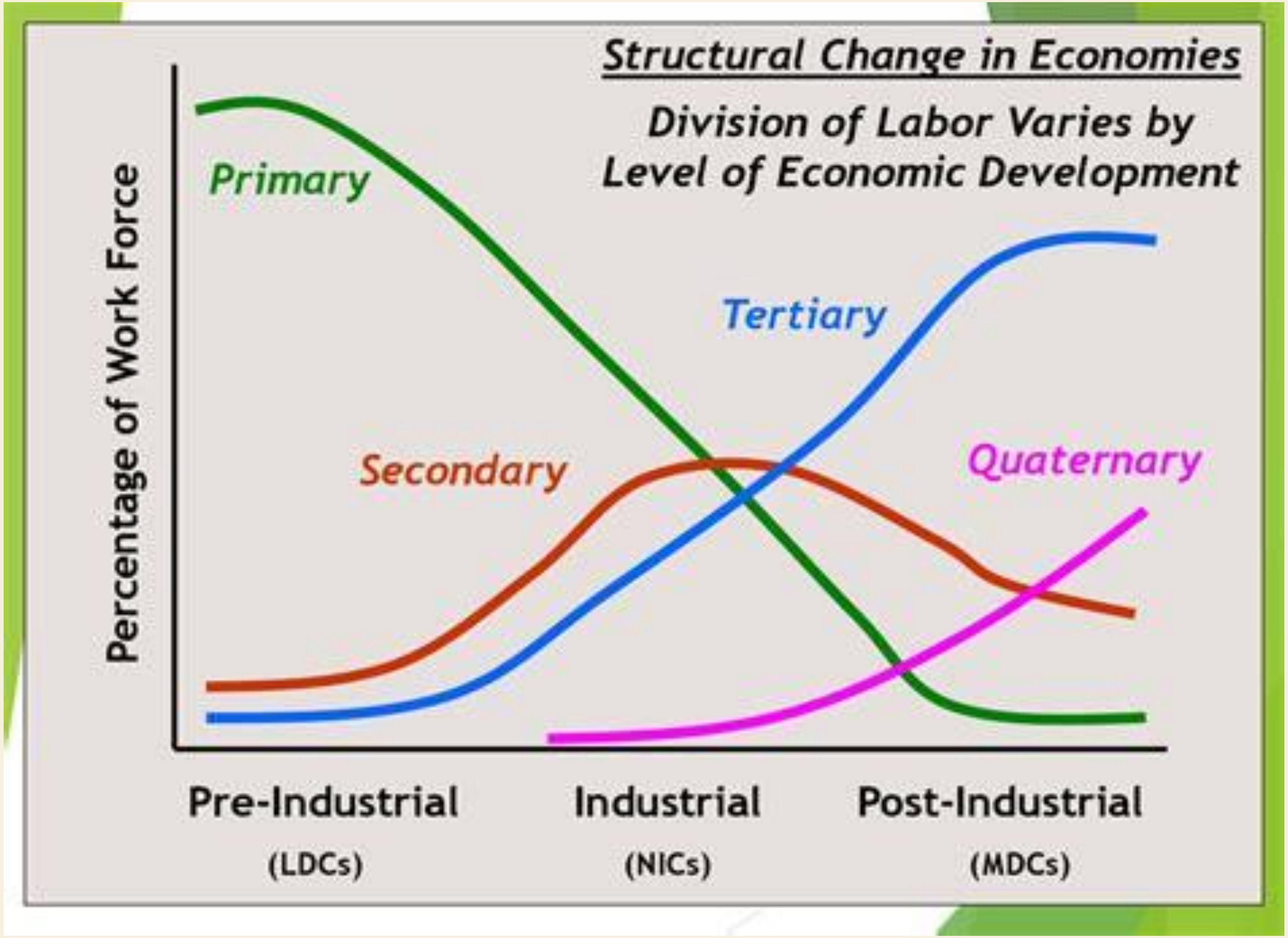
Agriculture sector's share of gross domestic product in European countries in 2021 (in percent)



Source: World Bank



Employment effects of agriculture: tiny (and large chunk is done by immigrants)


Structural Change in Economies
Division of Labor Varies by Level of Economic Development
Percentage of Work Force
Primary
Tertiary
Secondary
Quaternary
Pre-Industrial
(LDCs)
Industrial
(NICs)
Post-Industrial
(MDCs)

Income support per farmer (€)	Farmers (%)	Income support (€)	Income support (%)
< 500	25,0	531.338	1,3
500 - 1250	24,1	1.273.432.000	3,1
1250 - 5000	26,9	4.536.583.000	10,9
> 5000	24,0	35.216.169.000	84,7

Distribution of income support for farmers in 2017, Source: European Commission

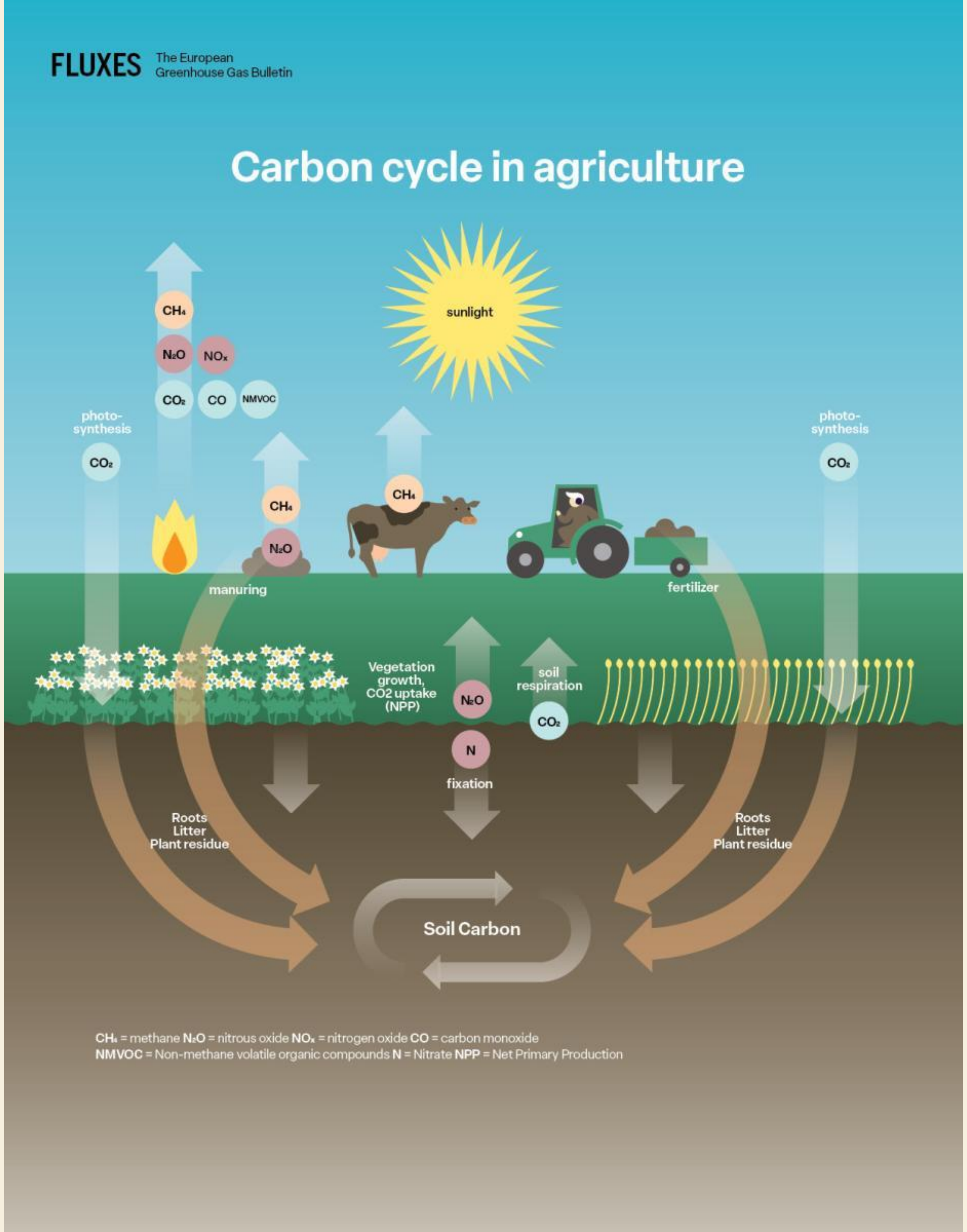
- As farmers receive an amount per hectare, larger farms receive more money.
- 24% of farmers received more than 5000 euros: a total of 1.6 million farmers
- These farmers together received almost 85% of all European agricultural subsidy
- About 15% of all farmers receiving European agricultural support
- **20% of the farmers receive approximately 80 percent of agricultural support money**

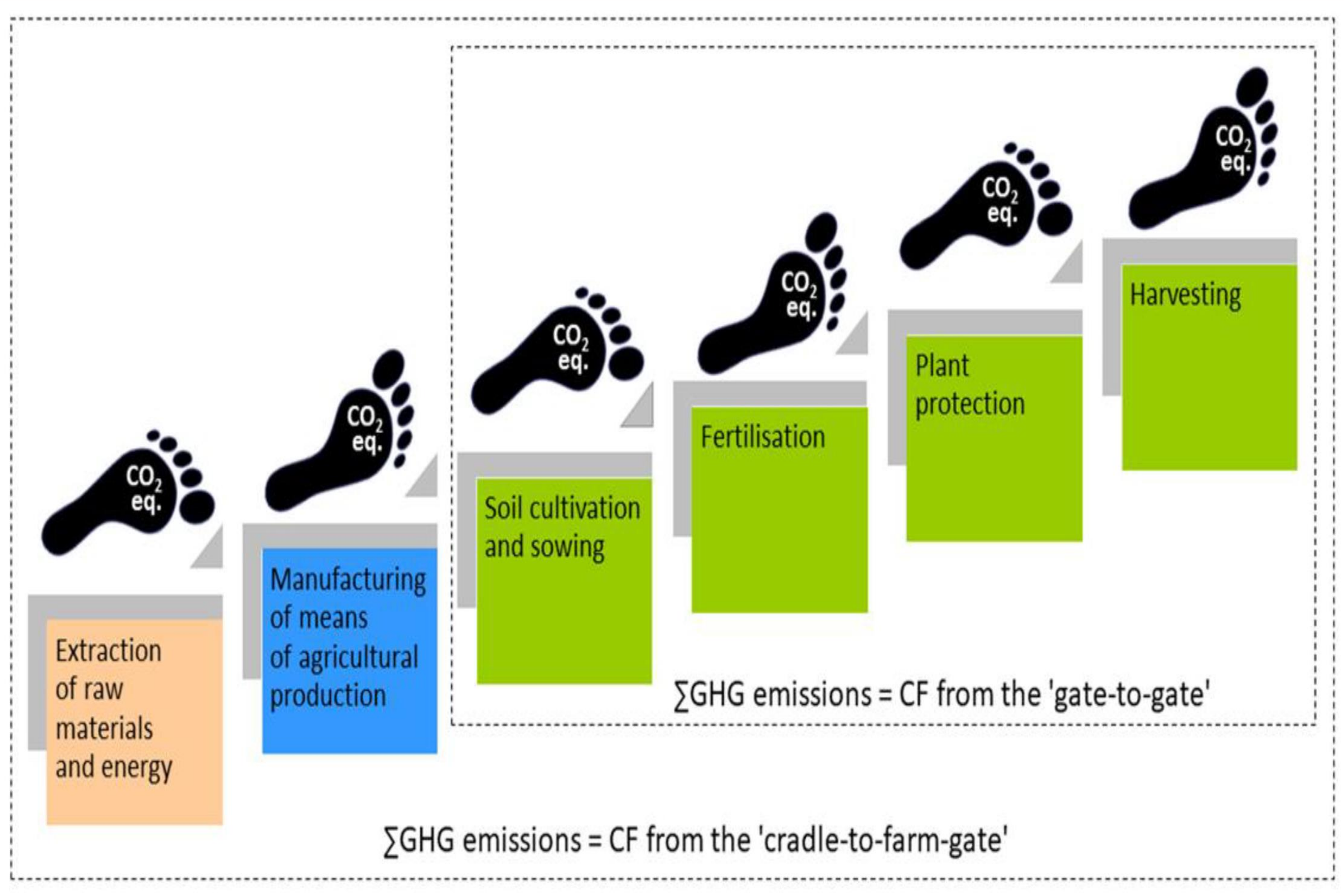
LANDBOUW KLEINE SECTOR MET BUITENPROPORTIONELE

VEEL POLITIEKE INVLOED

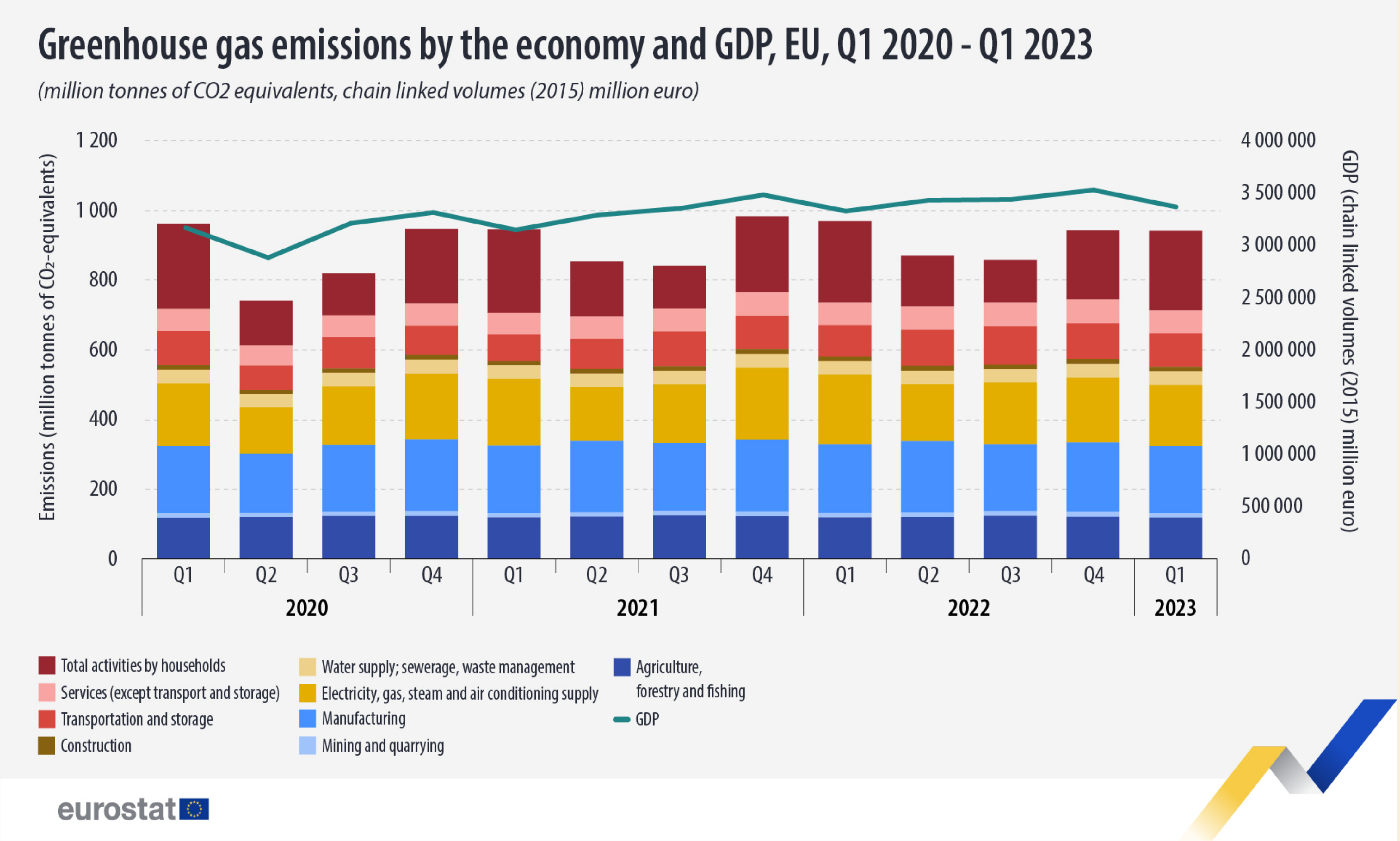
BOER
BURGER
BEWEGING

CLIMATE CHANGE AND AGRICULTURE

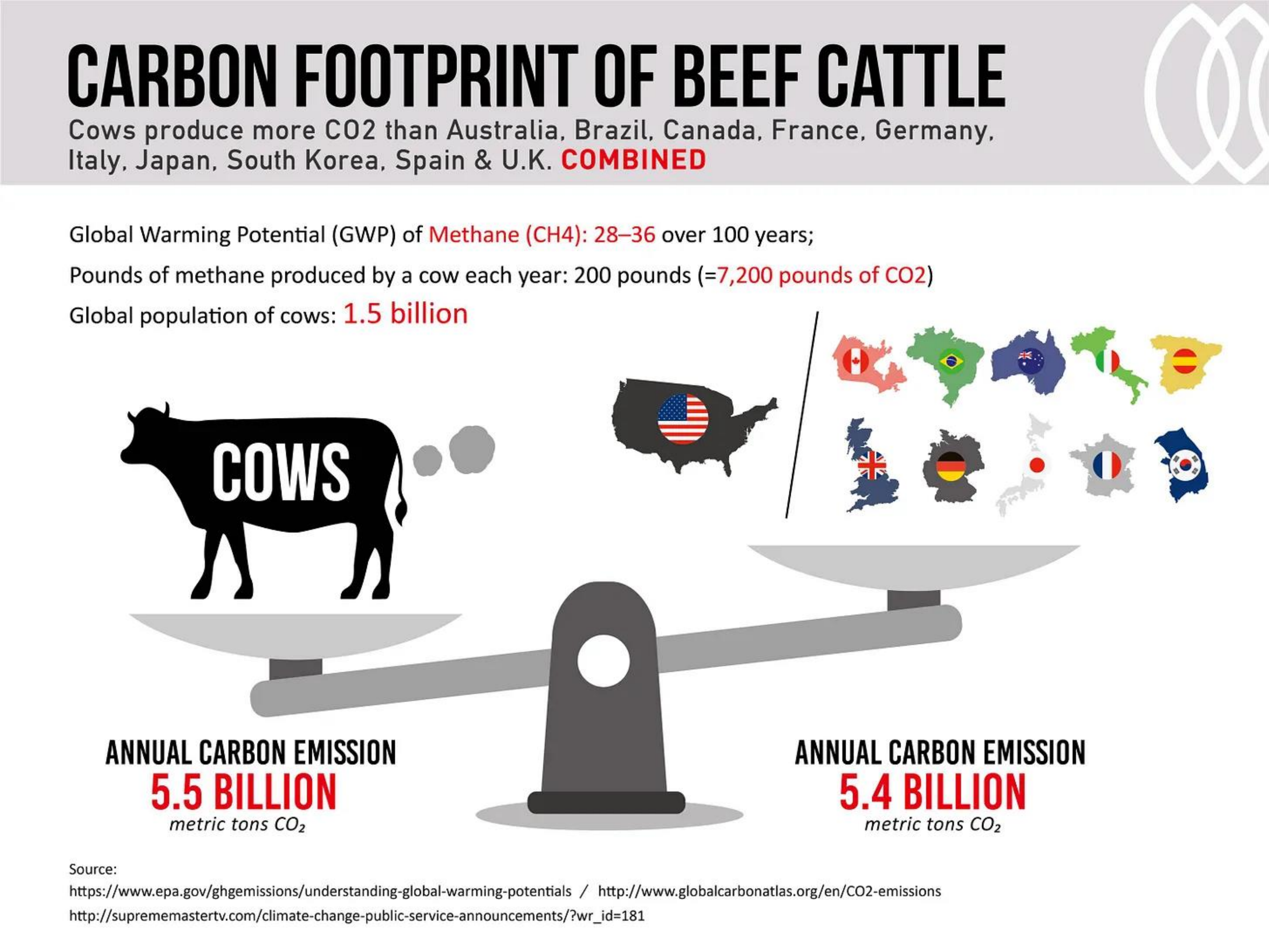

FLUXES The European Greenhouse Gas Bulletin
Carbon cycle in agriculture
sunlight
CH₄
N₂O
NOₓ
CO₂
CO
NMVOC
photo-synthesis
CO₂
CH₄
N₂O
CH₄
manuring
fertilizer
Vegetation growth, CO2 uptake (NPP)
N₂O
soil respiration
CO₂
N
fixation
Roots
Litter
Plant residue
Roots
Litter
Plant residue
Soil Carbon
CH₄ = methane N₂O = nitrous oxide NOₓ = nitrogen oxide CO = carbon monoxide
NMVOC = Non-methane volatile organic compounds N = Nitrate NPP = Net Primary Production

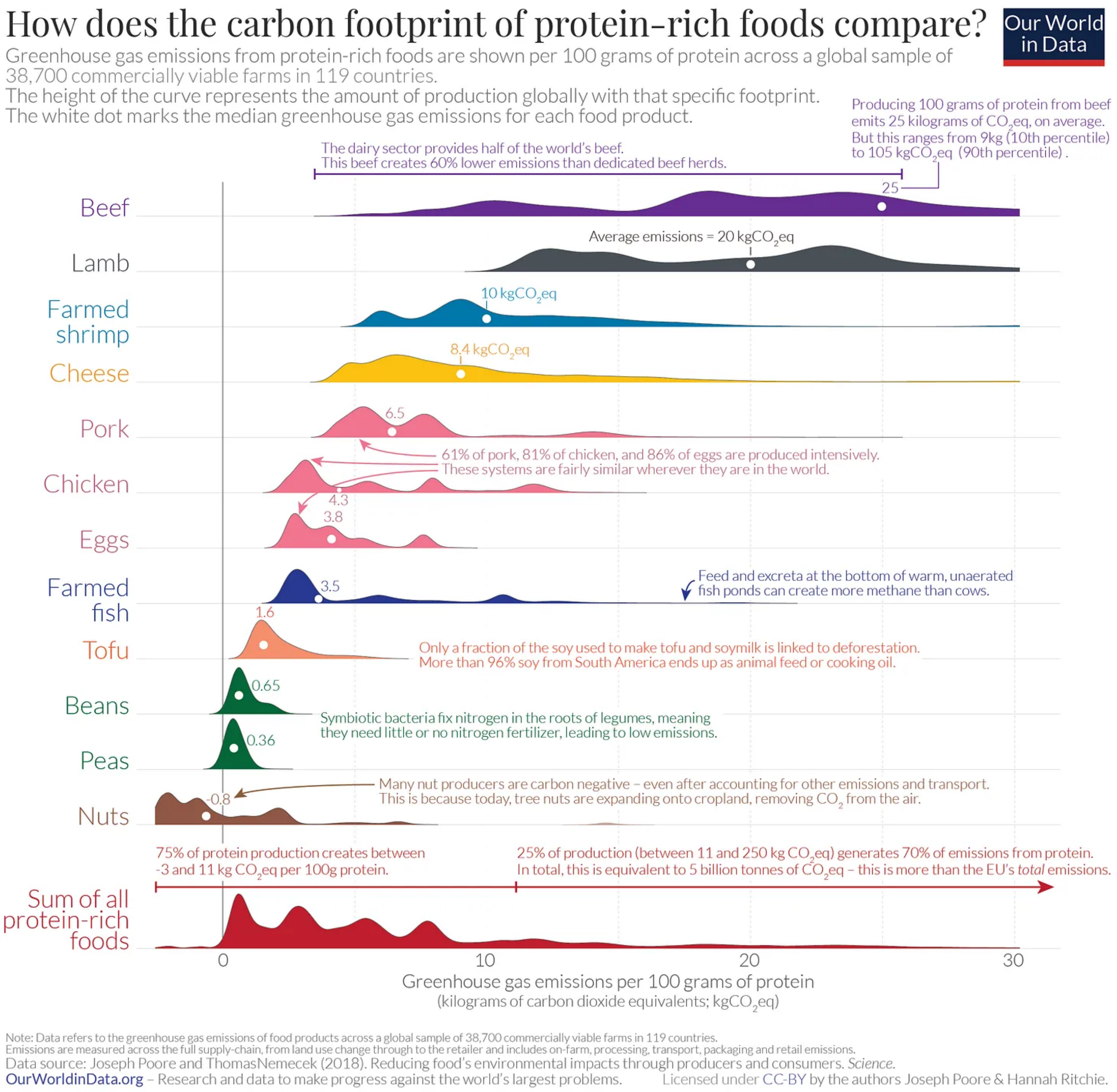


CO_2 eq.
Extraction of raw materials and energy
Manufacturing of means of agricultural production
Soil cultivation and sowing
Fertilisation
Plant protection
Harvesting
∑GHG emissions = CF from the 'gate-to-gate'
∑GHG emissions = CF from the 'cradle-to-farm-gate'



Greenhouse gas emissions by the economy and GDP, EU, Q1 2020 - Q1 2023
(million tonnes of CO2 equivalents, chain linked volumes (2015) million euro)
Emissions (million tonnes of CO2-equivalents)
1 200
1 000
800
600
400
200
0
GDP (chain linked volumes (2015) million euro)
4 000 000
3 500 000
3 000 000
2 500 000
2 000 000
1 500 000
1 000 000
500 000
0
Q1
Q2
Q3
Q4
2020
2021
2022
2023
Total activities by households
Services (except transport and storage)
Transportation and storage
Construction
Water supply; sewerage, waste management
Electricity, gas, steam and air conditioning supply
Manufacturing
Mining and quarrying
Agriculture, forestry and fishing
GDP
eurostat


CARBON FOOTPRINT OF BEEF CATTLE
Cows produce more CO2 than Australia, Brazil, Canada, France, Germany, Italy, Japan, South Korea, Spain & U.K. COMBINED
Global Warming Potential (GWP) of Methane (CH4): 28–36 over 100 years;
Pounds of methane produced by a cow each year: 200 pounds (=7,200 pounds of CO2)
Global population of cows: 1.5 billion
COWS
ANNUAL CARBON EMISSION
5.5 BILLION
metric tons CO_2
ANNUAL CARBON EMISSION
5.4 BILLION
metric tons CO_2
Source:
https://www.epa.gov/ghgemissions/understanding-global-warming-potentials / http://www.globalcarbonatlas.org/en/CO2-emissions
http://suprememastertv.com/climate-change-public-service-announcements/?wr_id=181


How does the carbon footprint of protein-rich foods compare?
Our World in Data
Greenhouse gas emissions from protein-rich foods are shown per 100 grams of protein across a global sample of 38,700 commercially viable farms in 119 countries.
The height of the curve represents the amount of production globally with that specific footprint.
The white dot marks the median greenhouse gas emissions for each food product.
Producing 100 grams of protein from beef emits 25 kilograms of CO_2eq, on average. But this ranges from 9kg (10th percentile) to 105 kgCO_2eq (90th percentile) .
The dairy sector provides half of the world's beef. This beef creates 60% lower emissions than dedicated beef herds.
Beef
25
Lamb
Average emissions = 20 kgCO_2eq
Farmed shrimp
10 kgCO_2eq
Cheese
8.4 kgCO_2eq
Pork
6.5
61% of pork, 81% of chicken, and 86% of eggs are produced intensively. These systems are fairly similar wherever they are in the world.
Chicken
4.3
Eggs
3.8
Farmed fish
3.5
Feed and excreta at the bottom of warm, unaerated fish ponds can create more methane than cows.
Tofu
1.6
Only a fraction of the soy used to make tofu and soymilk is linked to deforestation. More than 96% soy from South America ends up as animal feed or cooking oil.
Beans
0.65
Symbiotic bacteria fix nitrogen in the roots of legumes, meaning they need little or no nitrogen fertilizer, leading to low emissions.
Peas
0.36
Nuts
-0.8
Many nut producers are carbon negative – even after accounting for other emissions and transport. This is because today, tree nuts are expanding onto cropland, removing CO_2 from the air.
75% of protein production creates between -3 and 11 kg CO_2eq per 100g protein.
25% of production (between 11 and 250 kg CO_2eq) generates 70% of emissions from protein. In total, this is equivalent to 5 billion tonnes of CO_2eq – this is more than the EU's *total* emissions.
Sum of all protein-rich foods
0
10
20
30
Greenhouse gas emissions per 100 grams of protein
(kilograms of carbon dioxide equivalents; kgCO_2eq)
Note: Data refers to the greenhouse gas emissions of food products across a global sample of 38,700 commercially viable farms in 119 countries.
Emissions are measured across the full supply-chain, from land use change through to the retailer and includes on-farm, processing, transport, packaging and retail emissions.
Data source: Joseph Poore and ThomasNemecek (2018). Reducing food's environmental impacts through producers and consumers. *Science*.
OurWorldinData.org – Research and data to make progress against the world's largest problems.
Licensed under CC-BY by the authors Joseph Poore & Hannah Ritchie.

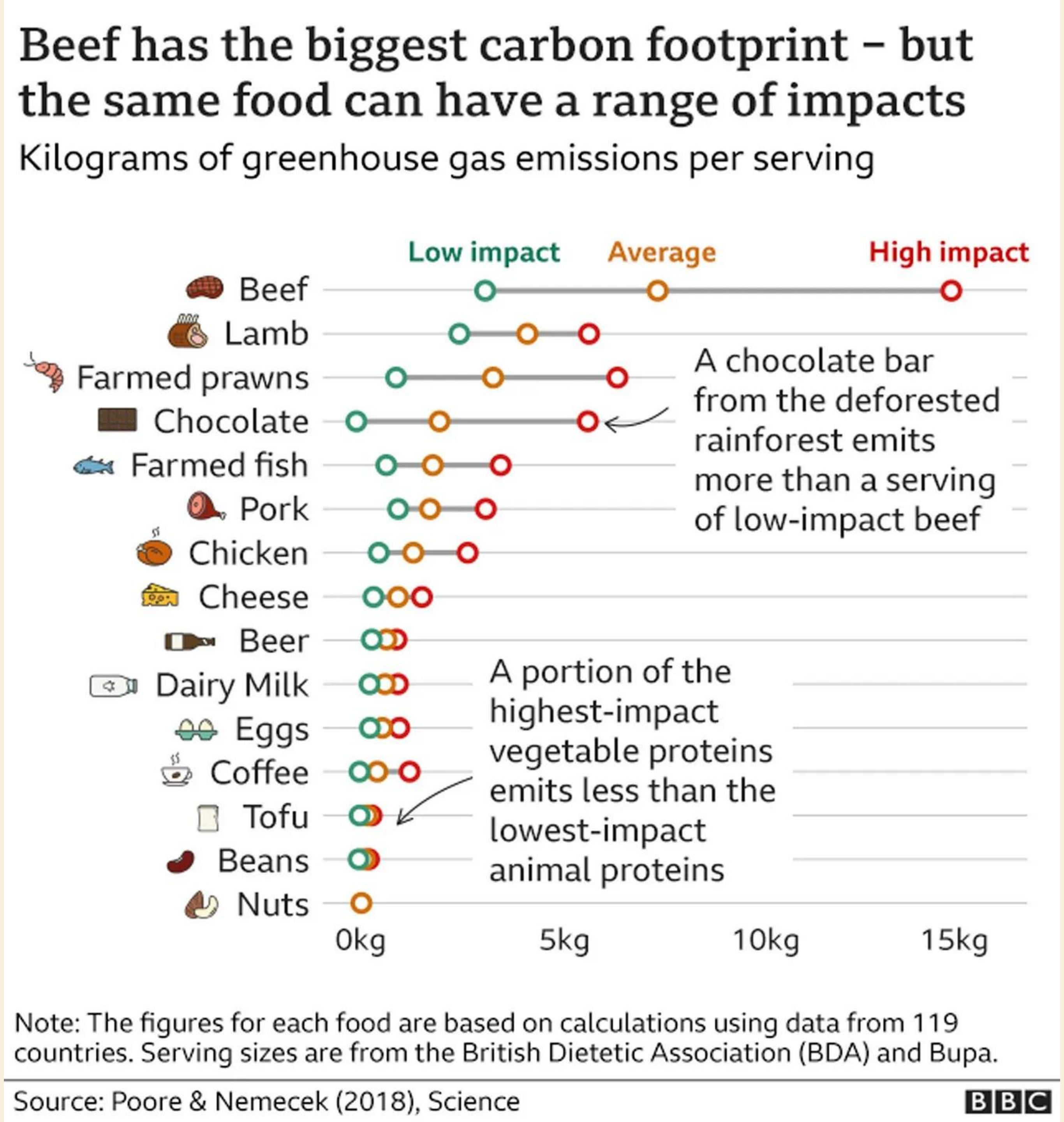

Beef has the biggest carbon footprint – but the same food can have a range of impacts
Kilograms of greenhouse gas emissions per serving
Low impact
Average
High impact
Beef
Lamb
Farmed prawns
Chocolate
Farmed fish
Pork
Chicken
Cheese
Beer
Dairy Milk
Eggs
Coffee
Tofu
Beans
Nuts
A chocolate bar from the deforested rainforest emits more than a serving of low-impact beef
A portion of the highest-impact vegetable proteins emits less than the lowest-impact animal proteins
0kg
5kg
10kg
15kg
Note: The figures for each food are based on calculations using data from 119 countries. Serving sizes are from the British Dietetic Association (BDA) and Bupa.
Source: Poore & Nemecek (2018), Science
BBC

Fig. 2: Projected end-of-century change in crop yields from climate change, accounting for adaptation to climate and increasing incomes

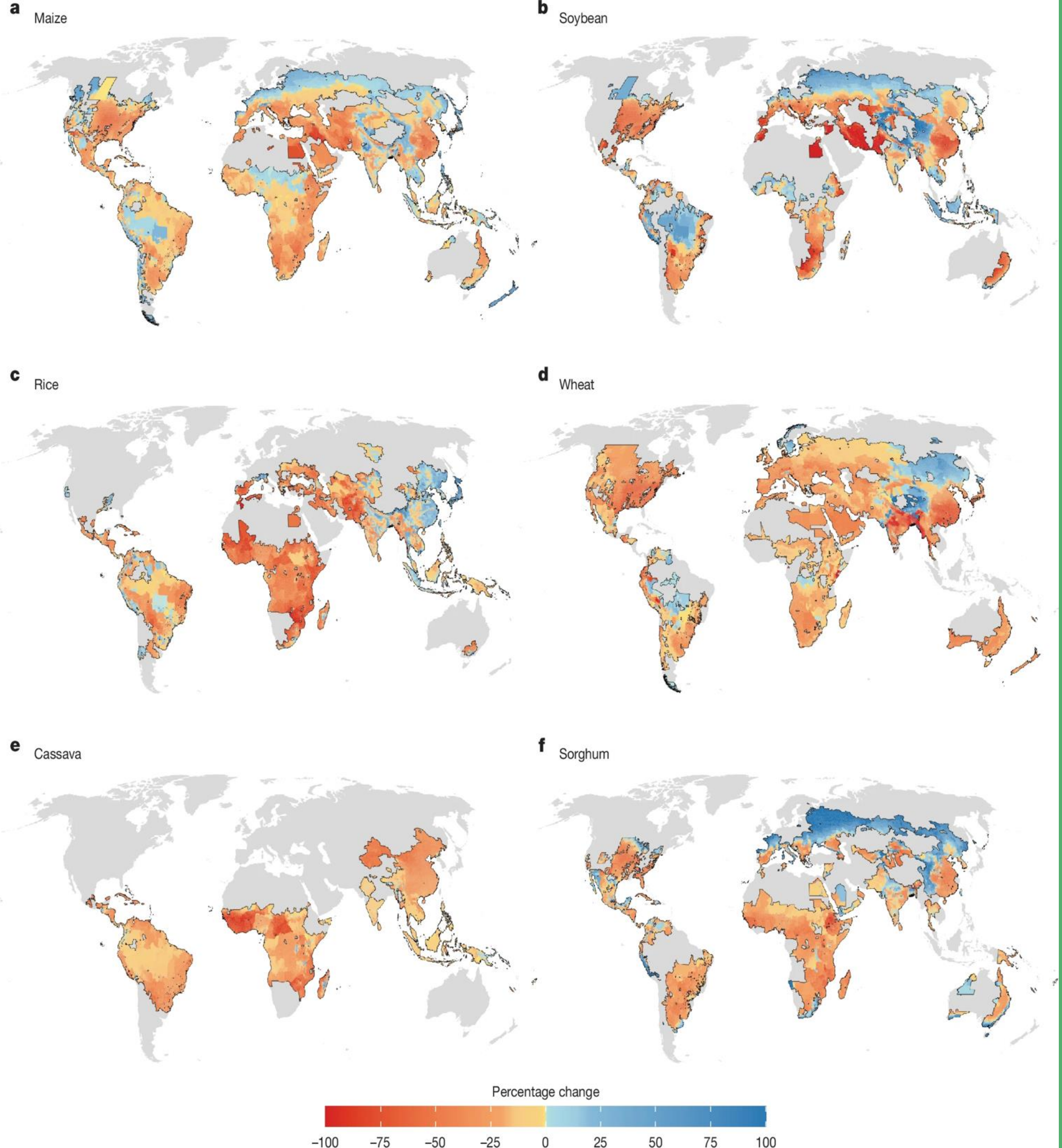
Detail: 12,600 regions, 54 countries, 6 crops

Take aways: for every 1degree rise, food production capacity drops by 120 calories per person (3 degrees is like everyone giving up breakfast);

under moderate emissions growth, central estimates in 2100, with adaptation and income growth: -12% for corn, -13.5% for wheat, -22.4% for soybeans;

adaptation and higher wealth alleviate 6% of global losses in 2050 and 12% in 2100

Source: Hultgren et al. (2025, Nature)



$190/tCO2 = $ 697/tC

$1,600/tCH4 = 2,133$ /tC

Methane is more aggressive but shorter lived than CO2

Social cost of a ton of carbon is three times higher

Remark: Bilal and Kaenzig (2025) get five times higher SCC of $1000/tCO2!

Source: EPA 2023

Social Cost of Carbon [1]

EPA Final Estimates (2020$ per metric ton of CO2)

Year of Emissions	2.5% Discount Rate	2% Discount Rate [2]	1.5% Discount Rate
2020	120	190	340
2025	130	210	360
2030	140	230	380
2040	170	270	430
2050	200	310	480
2060	230	350	530
2070	260	380	570
2080	280	410	600

Social Cost of Methane

EPA Final Estimates (2020$ per metric ton of CH4)

Year of Emissions	2.5% Discount Rate	2% Discount Rate [2]	1.5% Discount Rate
2020	1,300	1,600	2,300
2025	1,600	2,000	2,700
2030	1,900	2,400	3,200
2040	2,700	3,300	4,200
2050	3,500	4,200	5,300
2060	4,300	5,100	6,300
2070	5,000	5,900	7,200
2080	5,800	6,800	8,200

CARBON BORDER ADJUSTMENT MECHANISM (CBAM) AND AGRICULTURE

- CBAM applies to several fertilisers and raw materials, including nitric acid, sulphuric acid, ammonia (both anhydrous and aqueous), nitrates of potassium, and mixed fertilisers containing nitrogen, phosphorus, and potassium.

- **Emissions profile**: Mainly from chemical processes and high energy use in manufacturing.

GENETICALLY MODIFIED (GM) AGRICULTURE AND BIODIVERSITY

Environmental impacts of genetically modified crops

(Noack et al., Science, 2024:

Only two GM traits have been widely adopted: herbicide tolerance and insect resistance.

Adopting crops with these traits affects crop losses, pesticide use, and other management actions, including tillage and crop diversity levels.

These changes in turn affect agricultural expansion, deforestation, pollution, human health, greenhouse gas emissions, and biodiversity.

The environmental impacts differ across geographic scales and GM traits, leading to both positive and negative effects.

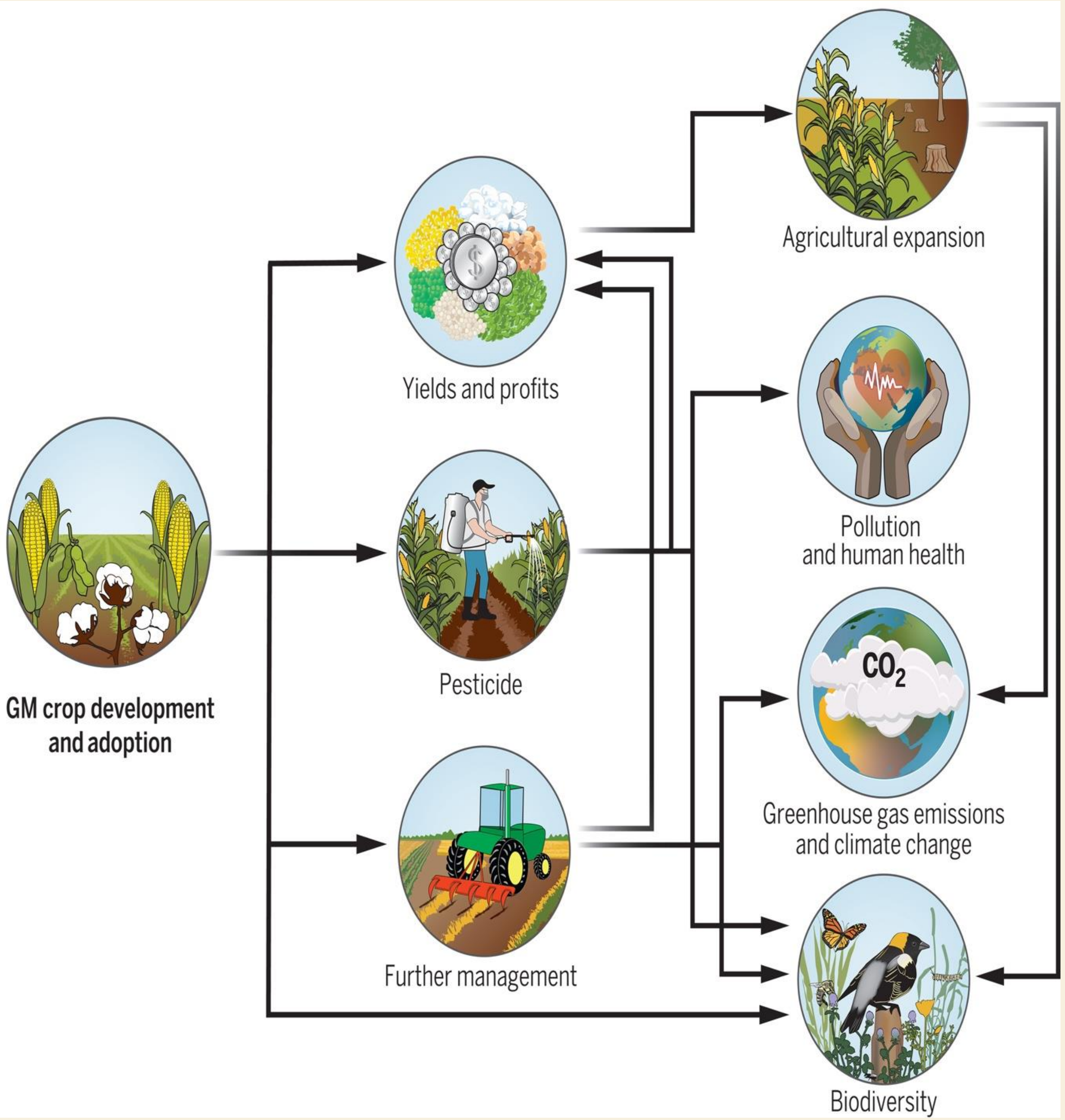


Fig. 1. GM crop adoption over time:
The percentage of global corn, cotton, soybean, and canola area under GM varieties.

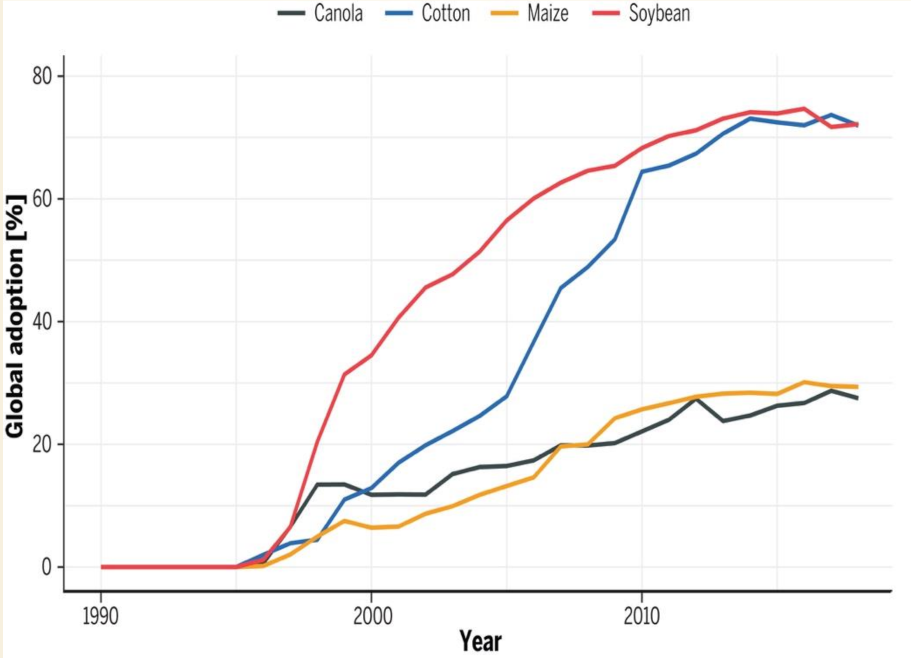


Fig. 2. GM crop adoption across countries:
Percentage of global corn, cotton, soybean, and canola cropland area planted with GM varieties in 2018. Countries with zero or less than 1% GM crop adoption are shown in light gray.

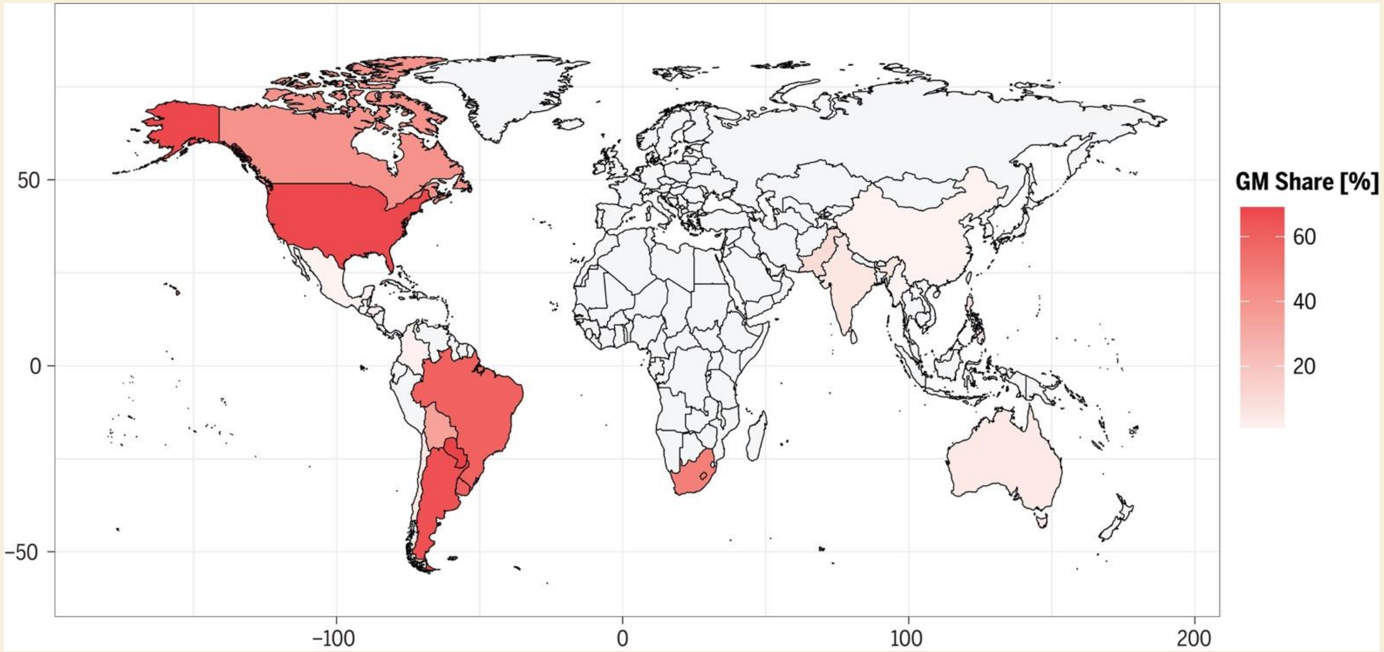
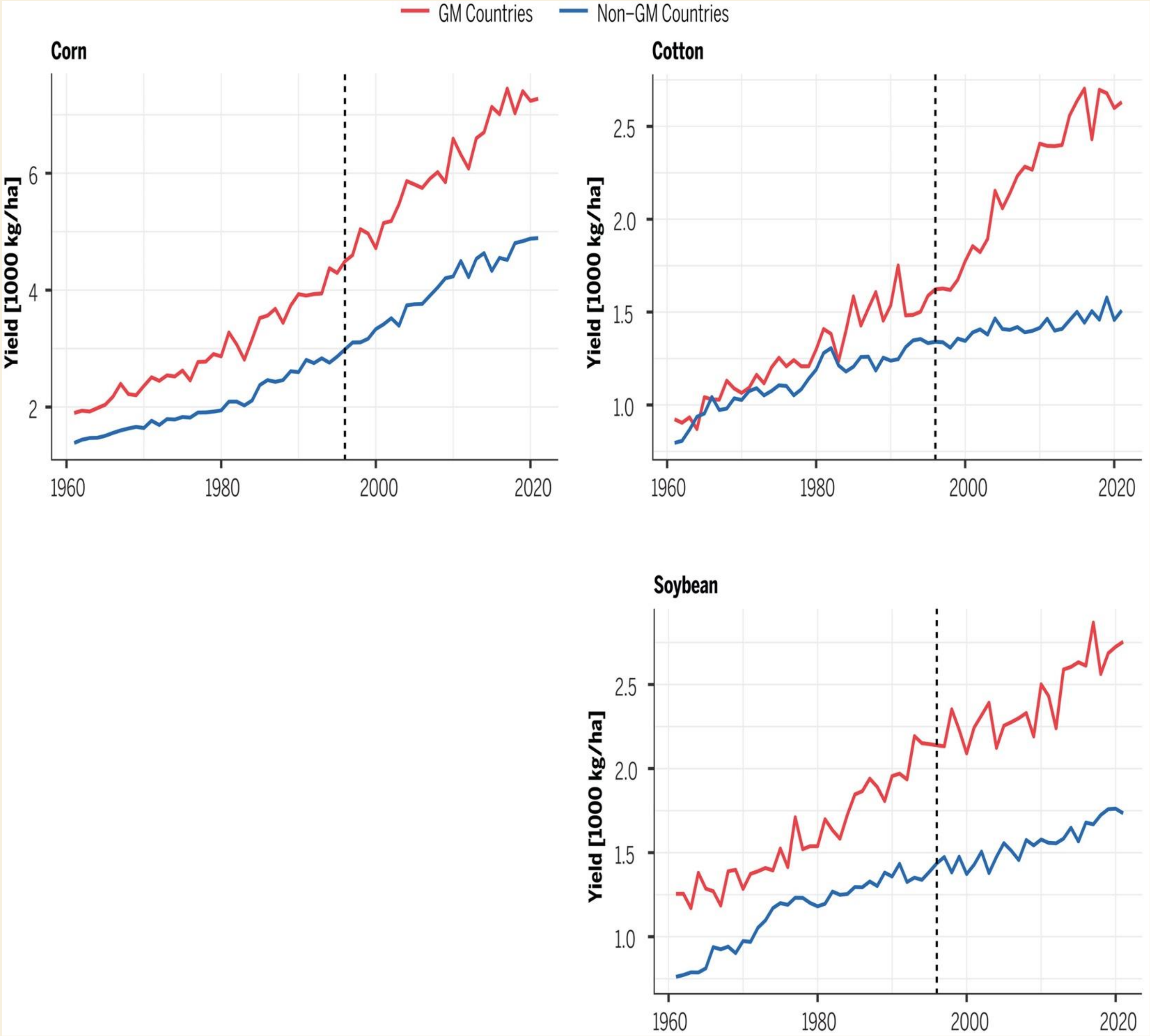


Fig. 3. GM crop adoption and crop yields:

The red lines are mean crop yields for countries with at least 10% adoption of GM corn, cotton, and soybeans in 2018, respectively.

The blue lines are the mean crop yields for the other countries.

The dotted line is the year of GM commercialization (1996), after which adopting countries started to increase the share of land under GM varieties.



GMO AND HERBICIDES AND PESTS

- Genetically modified organisms (GMOs) have been widely adopted, but their environmental impacts are not well understood
- Most common genetic modifications to crops provide resistance to herbicides or insect pests, which can lead to changes in pesticide use and other agricultural practices such as tillage and crop rotation
- These changes have downstream effects on human health, carbon cycling, and biodiversity
- Increased crop yields may reduce the need for converting additional land to agriculture, but increasing crop prices may encourage agricultural expansion
- More research is needed to assess the effects of GMO crop adoption on deforestation and biodiversity
- Genetically modified (GM) food more acceptable in US and UK

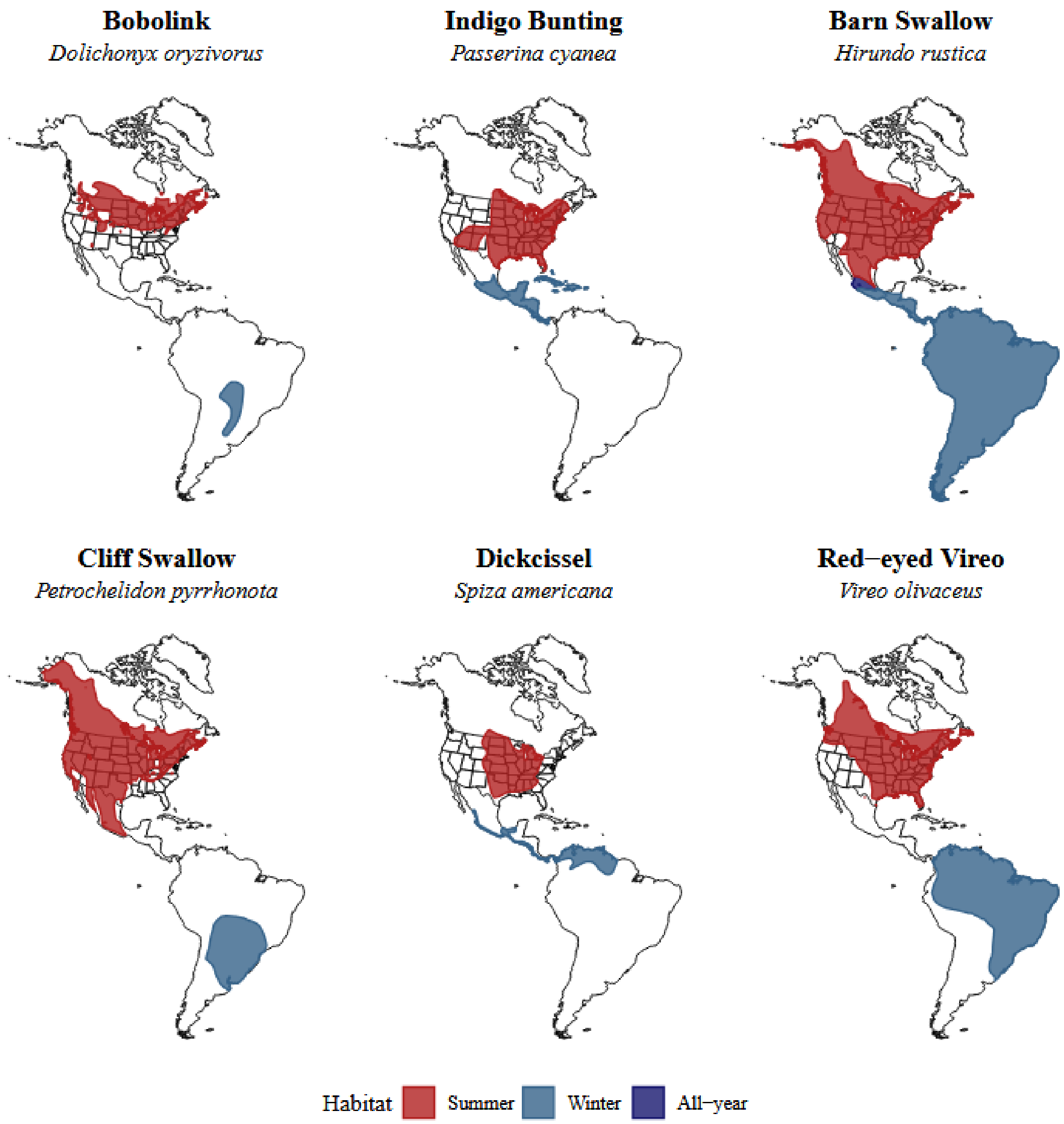
GM, BIRDS AND BIODIVERISTY

- **Engist et al. (2024), Nature sustainability:**
- Biodiversity provides essential ecosystem services to agriculture, including pest control and pollination, yet it is declining at an alarming rate, largely due to the agricultural sector.
- GM crops in the US $\Rightarrow$ major transformation of agricultural production, as over 90% of US corn, soybean and cotton areas are now planted with GM varieties.
- This shift in crop cultivation has substantially altered crop management practices, most notably the types and quantities of pesticides used.
- Estimate the causal impact of GM crops on bird diversity in the US and compare bird communities through time in areas with different levels of exposure to GM crops.
- Insectivorous birds benefit from GM crop adoption; this benefit is largest in cotton.
- In contrast, herbivorous birds weakly decrease with GM crop adoption.
- So, GM crop adoption has small positive effect on overall abundance of birds, the effect is heterogeneous across species groups, with potentially important consequences for bird community composition and associated ecosystem services in agricultural landscapes.

NEGATIVE EFFECT OF LESS TRANSMIGRATORY BIRDS ON AGRICULTURE

- Noack et al. (2025). Value of biodiversity: evidence from migratory birds
- Estimate economic value of biodiversity by estimating value of pest control services provided by migratory birds to US agriculture and forestry
- Exploiting exogenous variation in migratory bird returns driven by winter habit conditions in South America, a 10% drop in avian biodiversity cuts crop revenue by 1.1% and pushes up forest pest outbreaks by 1.2% (NB: total drop in birds was 30%)
- Ecosystem service in agriculture depends more on total abundance of birds, but for forests it depends more on the number of species
- Hence, biodiversity is a productive input!

Figure 2: Summer and Winter Distribution of Common Long-Distance Migratory Species



Notes: Winter (blue) and summer (red) habitat of six common long-distance migratory species.

Table 4: Main Results: Ecosystem Services and Agricultural Outcomes

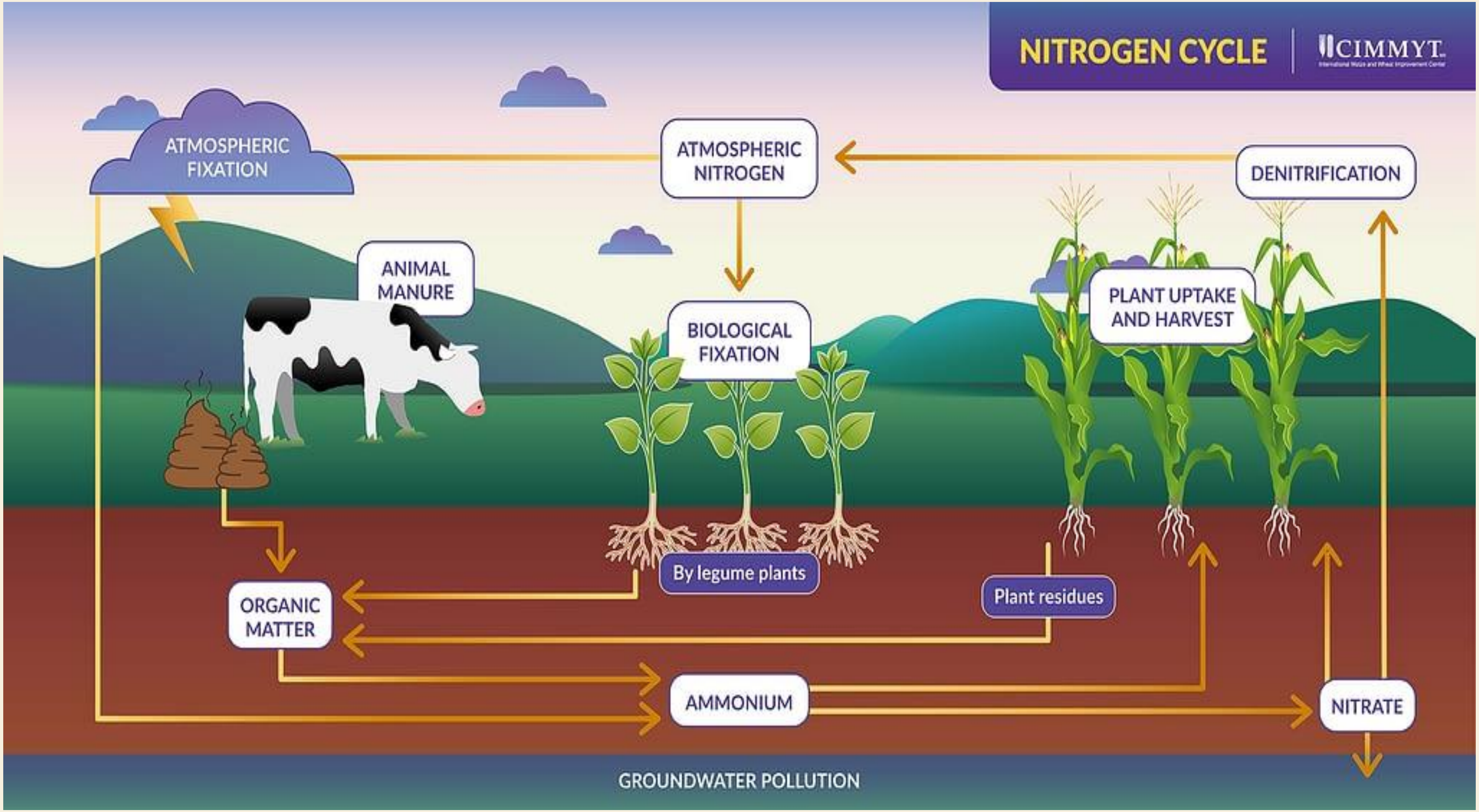
Outcome	Log(Sales)				Log(Yield)			
Elasticity	2	10	2	10	2	10	2	10
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log(ES)	0.095**	0.143**	0.070*	0.113*	0.082*	0.171**	0.058	0.149*
	(0.037)	(0.065)	(0.037)	(0.066)	(0.044)	(0.080)	(0.043)	(0.082)
Route-Segment FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes						
Year-State FE			Yes	Yes			Yes	Yes
Crop-Year FE					Yes	Yes		
Crop FE							Yes	Yes
Observations	62,917	62,917	62,917	62,917	241,638	241,638	241,638	241,638
Kleibergen-Paap	142.0	94.6	119.1	76.3	97.3	58.0	76.3	41.5

Notes: Standard errors are clustered at the county and route level. *, **, and *** indicate significance at the 10%, 5%, and 1% level. All specifications control for the share of migratory birds, Ihs $\left(\sum_{i=1}^{N} s_{ijt-1}^{\rho}\right)$, and ihs transformed growing degree days, killing degree days and precipitation in the current year. 'Kleibergen-Paap' is the first stage Kleibergen-Paap Wald Statistic.

NITROGEN ("STIKSTOF")

AND

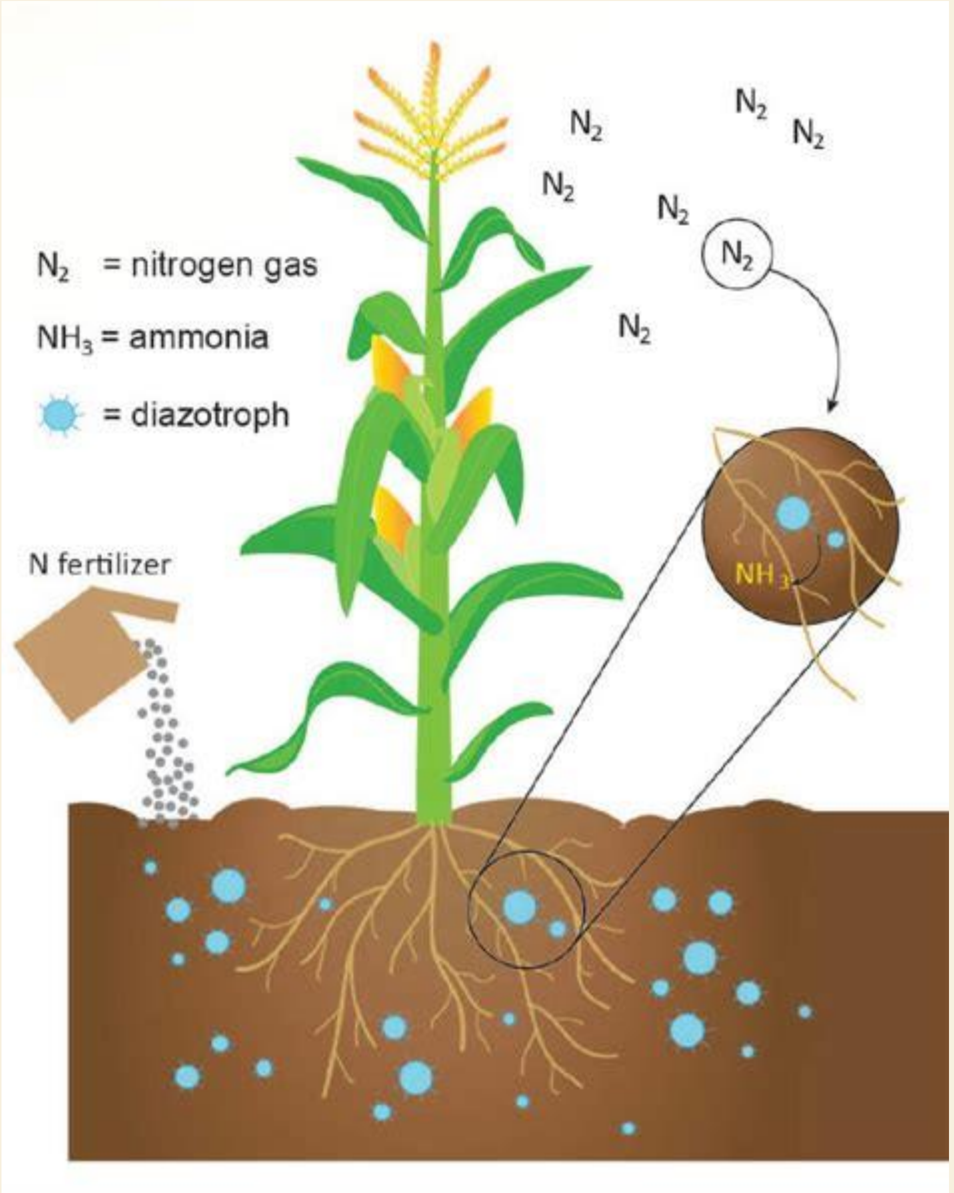
WATER CRISES


NITROGEN CYCLE
CIMMYT
ATMOSPHERIC FIXATION
ATMOSPHERIC NITROGEN
DENITRIFICATION
ANIMAL MANURE
BIOLOGICAL FIXATION
PLANT UPTAKE AND HARVEST
By legume plants
Plant residues
ORGANIC MATTER
AMMONIUM
NITRATE
GROUNDWATER POLLUTION

- Nitrogen benefits crop growth, soil productivity and agricultural productivity through fertilisers
- Nitrogen is crucial nutrient for plant growth and developments (part of enzymes, chlorophyl and nucleic acids, all needed for plants
- Synthetic nitrogen fertilisers are used to replenish soil nitrogen levels and boost crop productivity
- But nitrogen also harms the environment and so does manure: nitrogen leaching, runoff, emissions of NOx, contaminating ground water, rivers and lakes, and harm biodiversity
- Eutrophication, where abundance of nutrients boosts growth of algae and other plants
- Indirect costs: hit pollution limits so building of new offices, companies and houses is halted $\Rightarrow$ "nitrogen crisis"!

Replacing chemical fertiliser with nitrogen from soil bacteria:

Biological nitrogen fixation



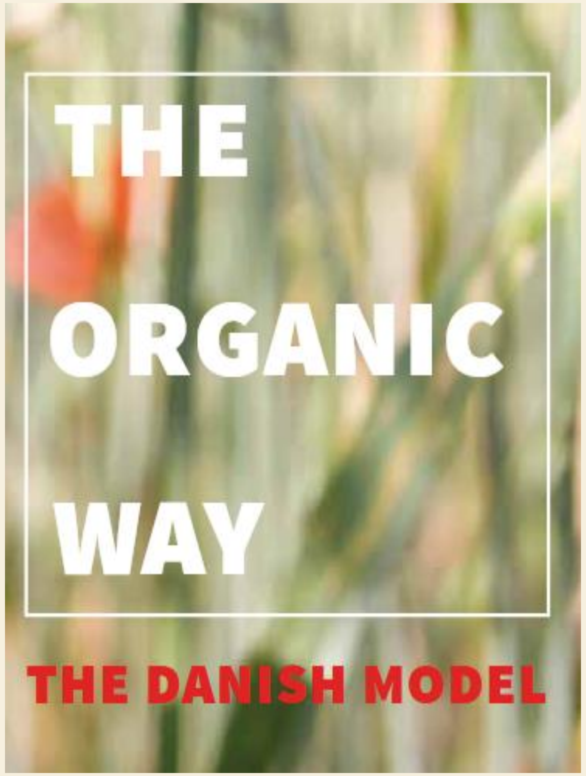
- Intensive agriculture (especially pigs and cows) have a very negative effect on ground water levels
- Soil degrades and sinks in, which hurts agricultural productivity among other things
- Water management is crucial as with global warming we get longer periods of drought followed by periods of intensive rainfall
- Key question is whether in future there is enough water for drinking, agriculture and industry without further depleting water levels
- Need innovative engineering solutions
- And perhaps new type of crops: blueberries, cranberries, rice, ..
- Also, reed, cattail, elephant grass etc.
- Get rid of paving and restore wild culture
- So, water can penetrate the soil again

“Rewilding” op de Hoge Veluwe

Het water kan weer het Leuvenumse Bos overstromen en in de grond zakken. Foto: Ralf Verdonschot

THE DANISH MODEL:

THE ORGANIC WAY



ORGANIC PRODUCTION is an overall system of farm management and food production that combines best environmental practices, focus on preservation of natural resources, a high level of biodiversity and application of high animal welfare standards.

Organic production is based on four principles: ecology, health, fairness and care. They have been formulated by the International Organic Organisation, IFOAM, and provide the basis for organic producers and their way of thinking and acting. They also form the basis of the laws and rules regulating organic production.

Before products can be sold as organic, organic farms have to go through a conversion period after starting organic plant and/or livestock production. The conversion period takes two years. During this transition period produce from the farm cannot be sold or labelled as organic.

THE IMPACT ON OUR ENVIRONMENT

Organic farmers work to preserve the natural environment, including soil fertility, water resources and biodiversity. The most important agricultural principles are:

- Careful monitoring of the soil's fertility, what farmers put in and take out of the soil, and how their activities affect its composition.
- Adopting a wide and varied crop rotation to break weed and pest cycles and to allow soil recovery time while supplying useful nutrients.
- Nutrients are provided by legumes (via biological nitrogen fixation from the atmosphere) as well as effective recycling of organic material such as crop residues and livestock manures.
- The primary use of preventive natural methods or mechanical methods to control weeds, diseases and pests.
- Non-use of chemical plant protection or synthetic fertilisers in order to protect the environment as a whole, including lakes, rivers, drinking water, etc.
- Planting of hedges and meadows to prevent soil erosion and nutrient loss.

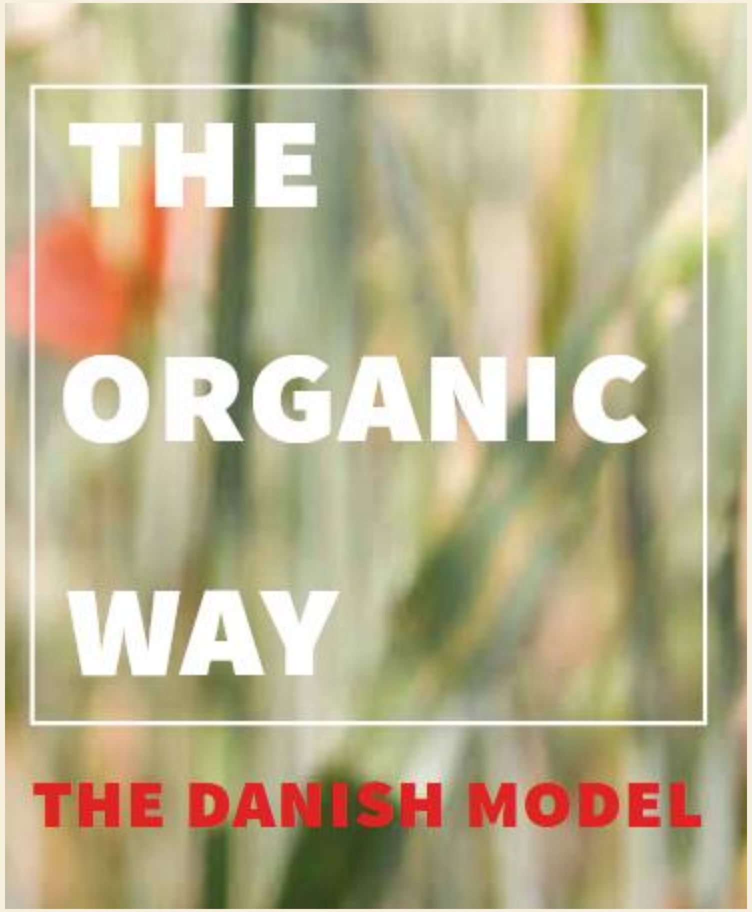
THE IMPACT ON BIODIVERSITY

Organic farmers preserve and enhance biodiversity as much as they can, i.e. by means of multi-annual crop rotations or by employing mechanical and physical methods of soil cultivation in order to achieve optimum results for soil health structure. Organic cultivation methods provide for more native plants and animals and a higher concentration of micro-organisms and earthworms in the soil.

THE IMPACT ON EMISSIONS

Studies from different universities in Europe have shown that organic agriculture can produce low carbon emissions per hectare of land and consequently may contribute to reducing climate change – even more so if yields in organic farming can be improved. Possible contributing factors include:

- Carbon sequestration in organic matter because organic farming enhances the humus content in the soil.
- Reduced energy consumption through recycling of waste and by-products.



- No use of synthetic fertilisers produced in energy-intensive processes.
- Retention of more native and general vegetation.

ANIMAL WELFARE

Animal welfare is an important feature of organic farming. The aim is to provide suitable conditions for natural behaviour. This means that:

- Animals have access to grassland or outdoor areas.
- Animals have ample space in their housing units.
- Animals eat organic feed.
- For cows, the number of animals is balanced with the area of available land.
- Any use of substances to promote growth or the use of hormones or similar substances to control reproduction or for other purposes is prohibited. Synthetic allopathic veterinary medicinal products are not used for preventive treatment.

NON-GMO

Use of genetically modified organisms (GMOs) and products produced from, or by, GMOs is not allowed.

PROCESSING OF ORGANIC FOOD

Only ingredients of natural origin are accepted when processing organic food. Only 53 of the 390 food additives approved in the EU are allowed in organic production. Synthetic flavourings, colorants, sweeteners, GMOs and irradiation are strictly prohibited.

HEALTHY FOOD

Studies comparing the nutritional quality of organic versus conventional products indicate the presence of certain health promoting factors in organic products:

- Organic dairy products and beef contain significantly higher levels of omega-3 fatty acid, linoleic acid and vitamin E.
- Organic fruit and vegetables have a higher level of antioxidants.

FOOD THAT MATTERS

- Organic food is authentic, high-quality and tasty.
- Organic labelling guarantees that all enterprises in the organic sector are regularly inspected by authorities.
- Organic production provides food without synthetic flavourings, colorants and sweeteners.
- Organic fruit and vegetables rarely contain traces of plant protection agents.
- Only a limited number of mostly natural additives are allowed in the processing of organic products.
- Genetically Modified Organisms (GMOs) are prohibited in organic farming and in the further processing of the products.
- Organic farming contributes to a high level of biodiversity and the preservation of species and natural habitats.
- Organic farming enhances soil life and natural soil fertility.
- As chemical plant protection is prohibited, organic farming contributes to the protection of the environment and can be practised in drinking water protected areas.
- Organic farming promotes animal welfare and provides good conditions for natural behaviour. All organic animals have access to outdoor areas.
- Use of antibiotics and other drugs is severely restricted. Organic animals are raised without the use of hormones.

CAP POST-2027 PROPOSAL


3 goals the EU Green Deal have on agriculture
Reduction of greenhouse gas emissions
A pledge to net-zero
Limiting methane emissions
Carbon farming
Enhancing biodiversity and ecosystem services
Beyond monocultures
Pollinators at the forefront
Reviving wetlands and forests
Sustainable land use and soil health
Regenerative over conventional
Soil as a carbon sink
Water conservation

- Farmers will continue to receive secure and reliable income support through a ring-fenced budget of at least €300 billion
- Member States will also tap into the new National and Regional Partnership Fund - an envelope totalling €865 billion - to finance the remaining CAP measures they need to put in place
- To help farmers cope with the impact of disturbances on agricultural markets, the Commission has doubled the amount of the crisis reserve (Unity Safety Net, €6.3 billion and is exclusively reserved for farmers)
- Finally, agriculture will also continue to benefit from European research – e.g. programmes for agriculture, health, the bioeconomy and biotech $\Rightarrow$ develop seeds that are more resistant to climate change or innovative applications in the bioeconomy, leading to additional revenue for farmers, for example.

- The structure of the CAP post-2027 is simplified and streamlined (EAFG and EAFRD – first and second pillar- will be merged)
- Support for farmers will be more targeted and fairer
- Environmental protection and climate action remain central, but the approach will shift from prescriptive conditions to rewarding positive actions. Farmers will receive clear incentives to adopt practices that benefit biodiversity, the climate, and animal welfare. A new transition payment, worth up to €200,000, will further support farms shifting to more sustainable models.
- Young farmers will receive unprecedented support
- Rural areas and innovation will also benefit
- Targeted market reforms to support growth of plant protein sector, protect traditional meat product designations, and introduce a legal basis for country-of-origin labelling in the future
- The future CAP protects incomes, rewards environmental stewardship, supports generational renewal, and strengthens the resilience of rural communities across Europe
- Listen to LIAS fellow Petra Berkhout who is an expert on the CAP!

FUTURE CHALLENGES AND OPPORTUNITIES

TRENDS

1. **Technology:** (i) big data, digitalisation, AI/ML, quantum computing, (ii) genetics: merger of synthetic biology with AI and quantum computing, synthetic production of food bypassing species and variety in its current form (labgrown meat)
2. **Financialisation:** separation of assets and production, away from conventional family farms
3. **Corporatisation and vertical integration:** encourages consolidation and large-scale farming at lower cost with more innovation
4. **Competing land uses:** 70% of land is agriculture now in UK $\Rightarrow$ vertical farming, large-scale farming indoors $\Rightarrow$ room for biodiversity, dwellings etc.
5. **Environment including water:** adverse effects of CO2, CH4 and nitrogen, less biodiversity and falling water levels, on agricultural productivity, but also reverse causation with agriculture harming the environment

Source: for first five points, see Dieter Helm (2025), https://dieterhelm.co.uk/publications/the-future-of-british-farming/

TRENDS

6. **Competing demand for space:** housing, firms, agriculture, nature
7. **Geopolitics:** Brexit; changes rapidly, populists more protectionist $\Rightarrow$ how to secure food security and how to re-arrange supply chains; developing countries: Fort Europe vs trade? What's Europe's comparative advantage?
8. **Political backlash and backtracking:** against immigrants and also more protectionist
9. **Demography:** population shrinking in Europe and growing in Africa; population projections United Nations may be much too high; sub-Sahara Africa $\Rightarrow$ population explosion and growing need for food, but might want to be self sufficient in cereals (van Ittersum et al., PNAS, 2025)
10. **Social changes:** children of farmers no longer want to put in the hard work (greying of the population)

WHAT CAN FARMERS DO

- Take advantage of innovation and finciancialisation
- Scale up
- Make use of new types of GM-AI designed crops
- Adapt to climate change and to protectionist climate
- Use less space and use the extra space to rewild
- Farm sustainably and circularly by minimising impact on climate, biodiversity, water and nitrogen

SMART AGRICULTURAL POLICY IN PERIOD OF RAPID CHANGE

- **Large-scale agribusinesses:** more capital intensive, heavy use of AI and data management, professionalisation of workforce, private equity, M&As
- **Upland landscape farming:** about grass, cattle and sheep with marginal returns, need subsidy $\Rightarrow$ diversify into tourism and provision of ESs (e.g. National Parks)
- **Low-input farming, including regenerative and organic farming:** in between these two models, focus on less artificial fertilisers and pesticides and minimise tilling of soils, reduced irrigation; and hobby farms and sporting estates
- **Rewilding**

WHAT CAN POLICY MAKERS DO

- Boost and redirect innovation towards sustainable agriculture with green R&D subsidies (e.g. heat resistance crops, synthetic crops using AI and GM)
- Investment funds for agriculture
- Make sure new power blocs do not do "protein washing" (meat industry lobby) and fight cartels that threaten to result from financialisation and innovation explosion

WHAT CAN POLICY MAKERS DO

- Price in all social costs of CO2, methane, nitrogen, water etc. and rebate the revenue to make it politically acceptable and finance subsidies (Meat tax? Social cost due to nutrient pollution and impact on climate change is an extra \$6 - \$10 per kilo, much more if effects on biodiversity and diet-related health are included)
- Change eating habits (veggies, beans, insects): meat tax, nudges, education
- Income and environmental services support rather than price support; agricultural subsidy is still large but needs to be redirected

WHAT CAN POLICY MAKERS DO

- Use ETS revenues including those from the CBAM (e.g. fertilisers) for innovation in the agricultural sector and income support
- Using innovations and new finance allows move to large-scale farming but make sure that the free land is used for rewilding, nature, recreation and tourism
- If the freed land is re-used for housing or industry, make sure to cream of the rents with a Henry George tax
- Support ecological agriculture as well as more industrial-scale agriculture; organic agriculture (Danish model)
- Move towards self-sufficient sustainable agriculture (e.g. beans and pulses) needs support too to ensure food remains affordable for lower-income groups