SCOTLAND'S GLOBAL FOOD SECURITY CONFERENCE

EDINBURGH | 5-7 NOVEMBER 2025

GLOBAL FOOD SECURITY: CLIMATE CHANGE, COLLABORATION, AND COMPARATIVE ADVANTAGE

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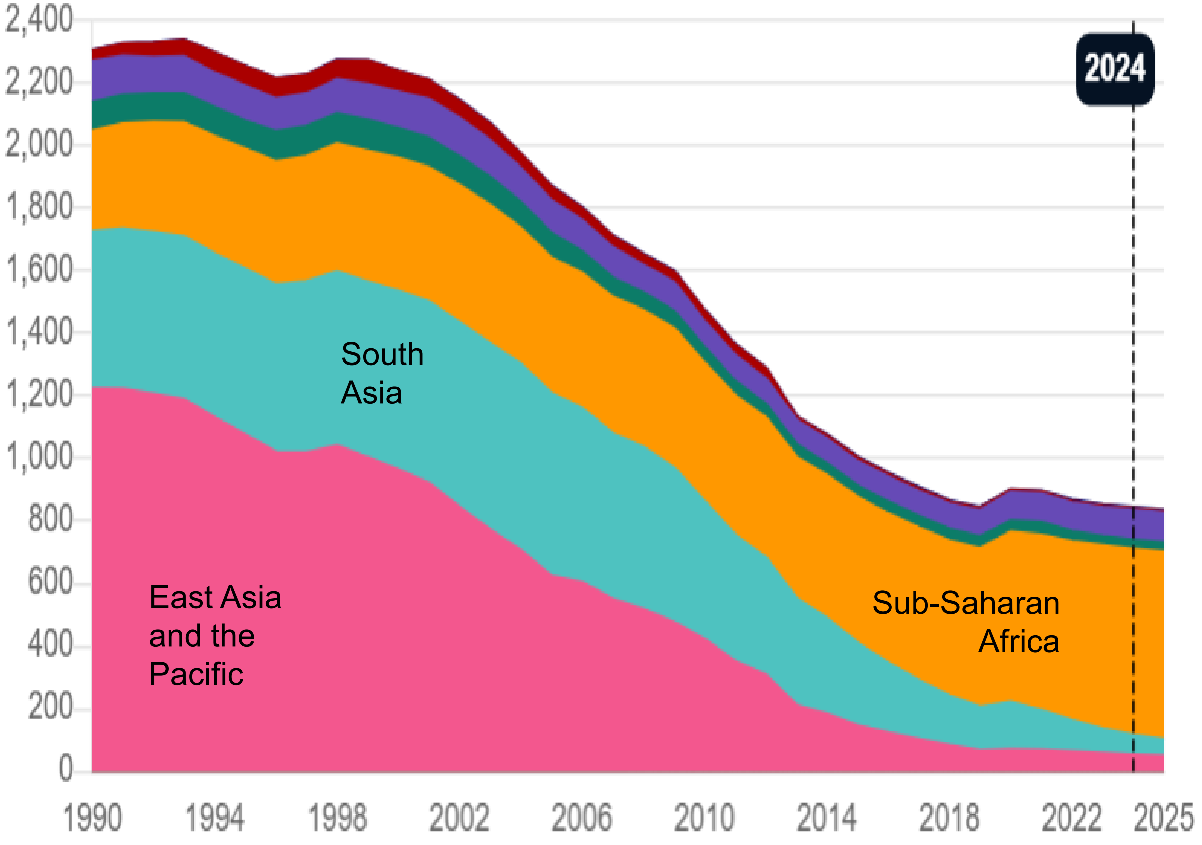
Achieving progress on global food security: innovation, finance and trade

Ruth Hill
Director, Markets, Trade and Institutions Unit, IFPRI

November 6, 2025

Unprecedented rates of improvement in global food security are no longer to be taken for granted

Number of people living on less than $3 per day

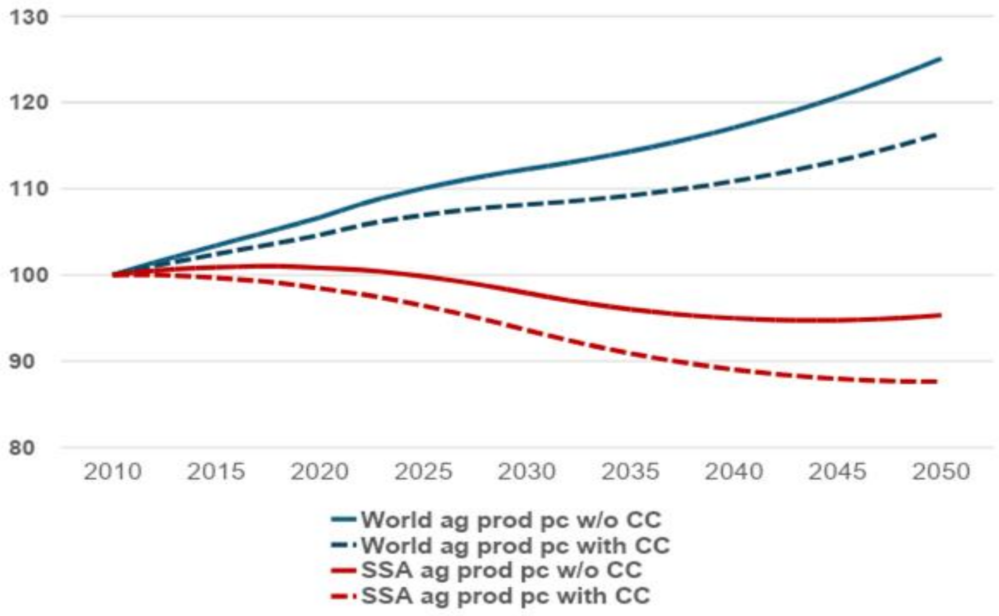


World Bank. 2025. Poverty and Inequality Platform

- Rapid growth led to reductions in poverty and food insecurity in Asia
- Rates of poverty reduction have not been large enough to keep up with population growth in Sub-Saharan Africa, particularly in recent years
- Global poverty increased with COVID and has stalled since.

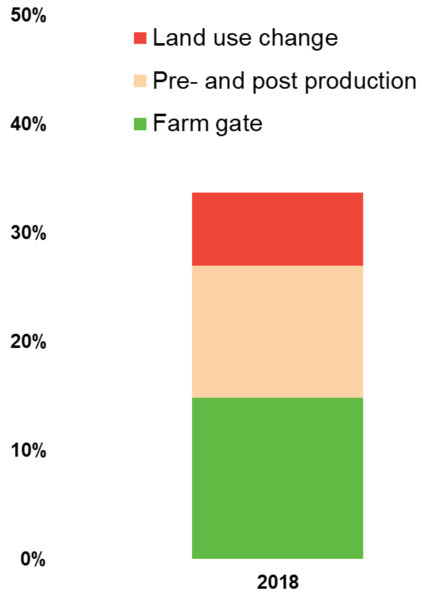
Challenge: increasing productivity sustainably and equitably

Current projections: global production growth is slowing and declining in Sub-Saharan Africa



Food System Contribution to Climate Change

(% of total GHG emissions)



Source: Projections based on IFPRI's IMPACT model (see IFPRI 2022) and UN Population Division for Population Projections (medium variant).

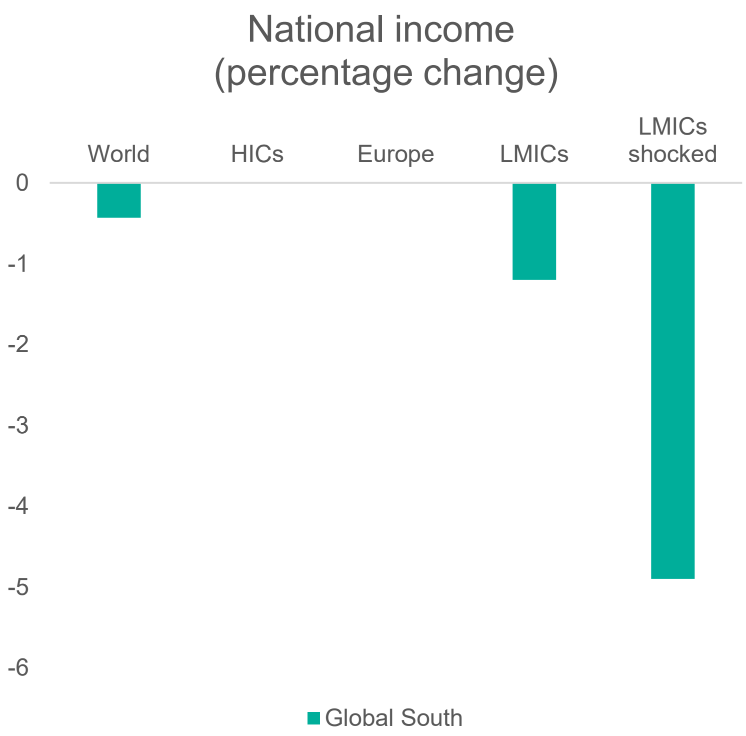
Gautam 2024

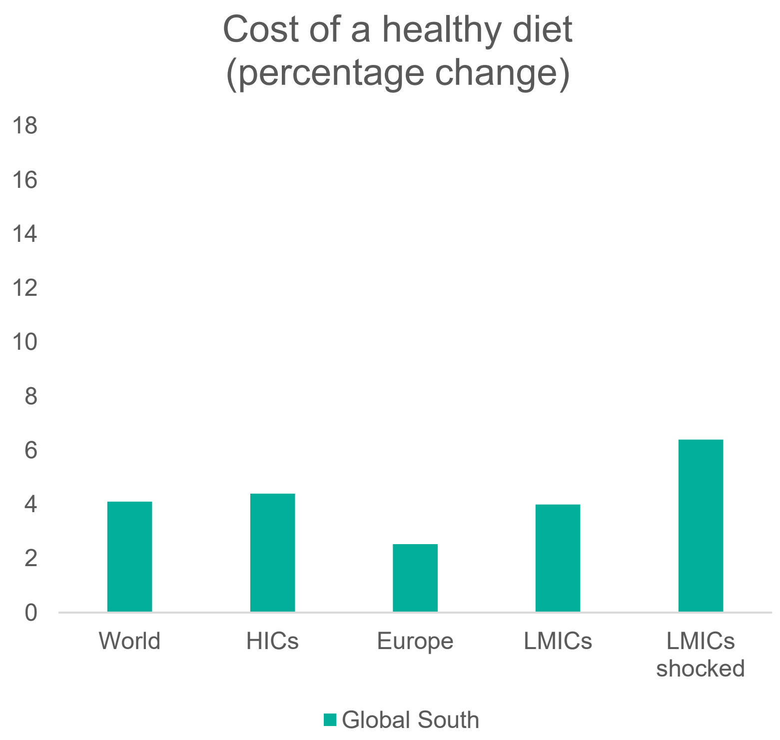
In the face of an increasingly risky climate

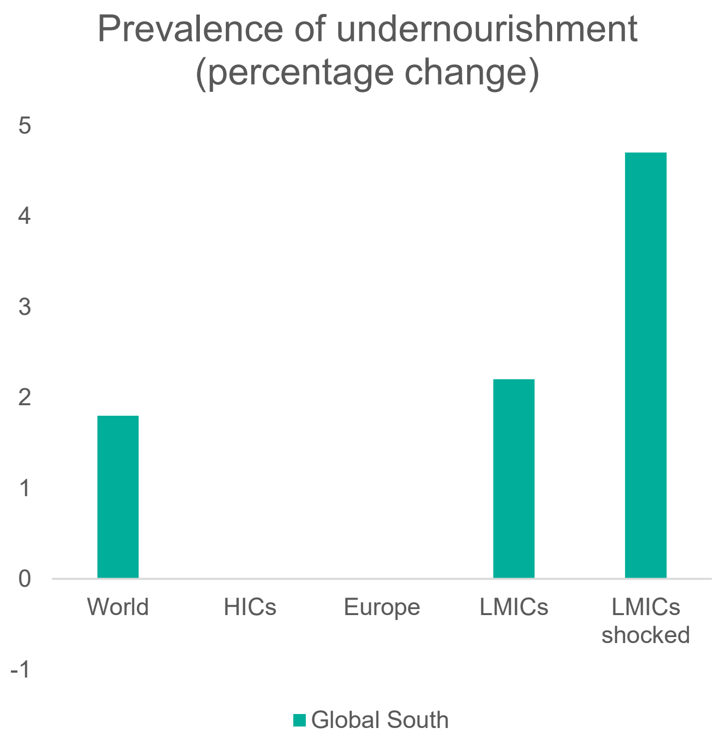
- Climate change is increasing the risk of crop failure and increasing the risk of simultaneous crop failure in multiple bread baskets.
- Estimates of how much this risk is increasing vary
  - Climate risk is unquestionably increasing
  - Improved production practices and technologies have reduced the impact of climate risk on production over time (not everywhere)
- Impact on incomes, food prices and food insecurity

Global food security risk from multiple bread-basket failure

Failure: 25% reduction in yields of all crops



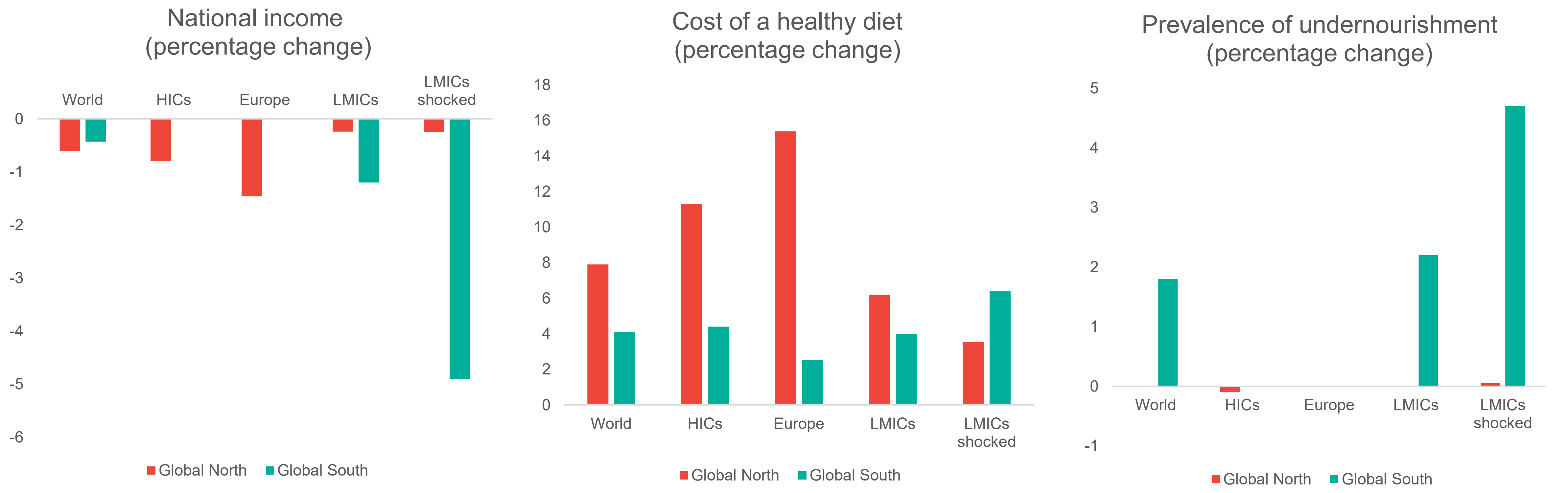




Martin, Nia and Vos. 2025.

Global food security risk from multiple bread-basket failure?

Failure: 25% reduction in yields of all crops



A failure in N. America and Europe has a larger impact on global incomes and prices, little impact on undernourishment

Innovation

The role of agricultural innovation

- Green revolution: most important episode of agricultural innovation in modern history.
- By 2020, CGIAR varieties had been introduced across more than 544 million acres of agricultural land in Asia, Africa, and Latin America, creating $47 billion in direct annual economic benefits
- Yields of food crops increased by 44 percent from 1965 to 2010
- This increased incomes, allowed households to educate their children, have fewer children, and move out of agricultural production into higher-return activities.
- GDP per capita would have been 17 percent lower in developing countries in 2010 without the investments in agricultural technologies made by CGIAR and others.

Fuglie, K. Echeverria, R. 2024. The economic impact of CGIAR-related crop technologies on agricultural productivity in developing countries, 1961–2020. *World Development*, *176*, 106523.
Gollin, D. Hansen, C. W. Wingender, A. M. 2021. Two blades of grass: The impact of the Green Revolution. *Journal of Political Economy*, *129*(8), 2344-2384.

This innovation had global benefits

65 percent of wheat grown in the U.K. can be traced back to CGIAR breeding material

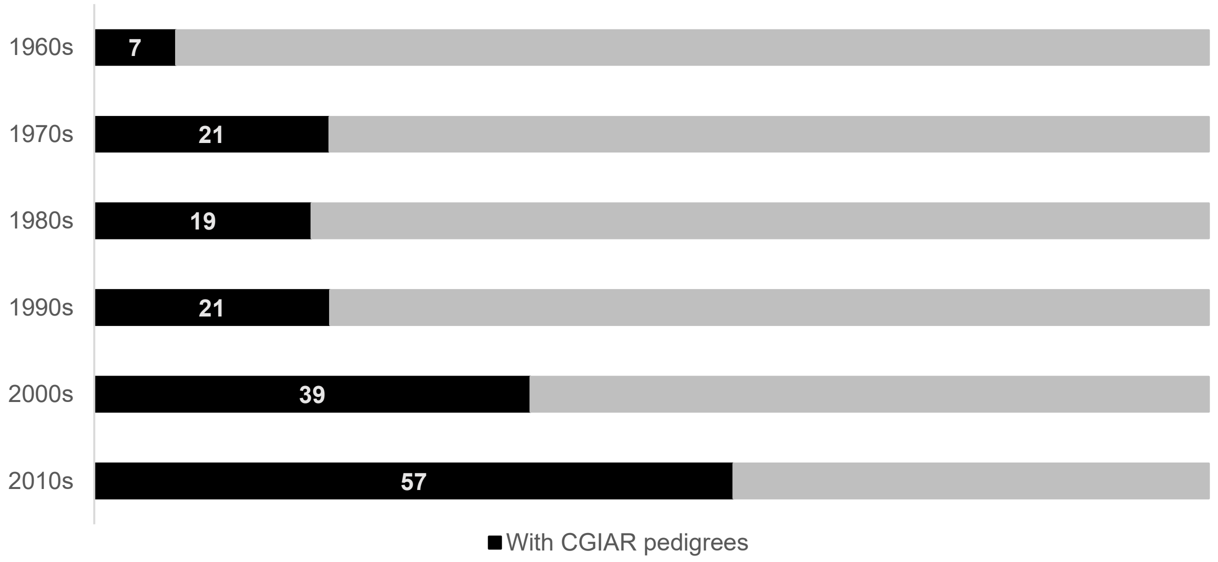


Figure 1. Share (%) of new wheat accessions in the UK with known pedigrees that contain CGIAR pedigrees, by decade and type

Source: Data compiled from GENESYS, the SeedStor public database maintained by the Germplasm Resource Unit of the John Innes Center, and Wheat:Gateway data.

CGIAR innovations brought substantial benefits to the UK

Farmers

British farmers to produce an additional 793,600 tons of wheat per year

GBP193 million in increased profitability annually since 1971

Exporters

An additional GBP2.6 billion in annual exports for the U.K.

These include British industrial equipment and consumer goods, as well as U.K. expertise in financial and technical services.

Consumers

Reduced the cost of a healthy diet in the U.K. by 1.2 percent, an annual saving of GBP 46 per family of four

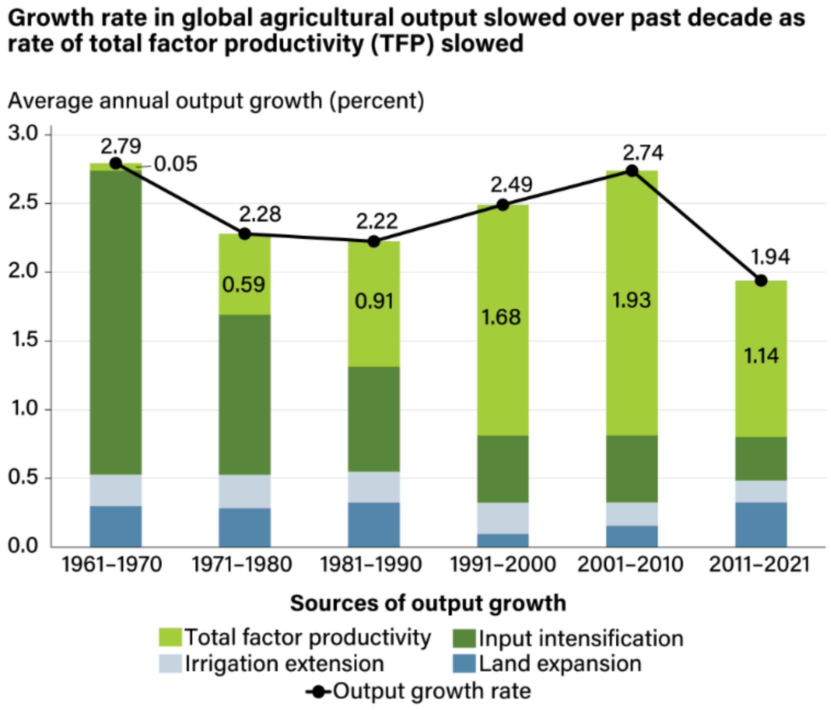
This has contributed to an increased amount of dairy, fruits and vegetables consumed by British families.

Ruth Hill, Will Martin, Brian McNamara, Reza Nia, David Spielman, Hiroyuki Takeshima, and Rob Vos. 2025. A Good Global Investment for the United Kingdom: How investing in CGIAR reduces global poverty and benefits U.K. citizens. Work funded by FCDO

Need for further innovation to drive future agricultural growth

- We have had two decades of fast agricultural growth, driven by technological improvements.
- This is slowing, bringing overall agricultural growth down.
- New sources of TFP growth needed

- New variety development: e.g. abiotic and biotic stress-tolerant varieties and quality seed. Innovations in feed, animal health



Note: **TFP** = total factor productivity. TFP measures the amount of agricultural output produced from the combined set of land, labor, capital, and material resources used in farm production. **Input intensification** is the increased use of resources per acre to increase production.

Source: USDA, Economic Research Service (ERS) using the ERS International Agricultural Productivity data product, September 2023 update.

Fuglie, Morgan and Jelliffe. 2023. World Agricultural Output and Productivity Growth Have Slowed

Innovations beyond agriculture are needed to enable investment by farmers in Africa

- On-farm investments in crop production are often found to be lower than expected throughout Africa despite the returns anticipated.
  - For example, use of inorganic fertilizer is very low

- Risk surrounding the return to the investment in any one season can make the investment not worth it, even if on average the return is positive.

- Need to reduce:
  - Production risk by improving soil quality and water management
  - Managing risk through financial markets

Innovation to support take-up of traditional techniques: rainwater harvesting and land management

Niger
Training supporting demi-lunes

- Farmers provided training to construct demi-lunes
- Results
  - Training increased adoption by 90pp
  - Increased production quantity and value = 0.12-0.15 std dev
  - Reduced vulnerability to drought

Source: Aker and Jack (2022)

Ethiopia
Payments for ecosystem services

- Households provided transfers in return for forest and land rehabilitation
- Results
  - Tree cover increase = 5%
  - Yield increases = 5%
  - Increases were higher for places experiencing drought (highlighting resilience) and accumulated over time (long-run benefits)

Source: Hirvonen et al. (2022); Constenla-Villoslada et al. (2022)

AI-enabled decision support innovations: allowing site and time specific application of nutrients

Ethiopia
Site-specific agronomic information

Farmers received site-specific nutrient management recommendations for maize

- Results
  - Increased urea + NPS use by 8.6 kg/ha
  - Increases in yield = 5%, profits = 13%

Source: Ayalew et al. (2022)

Nigeria
Digital delivery of personalized extension

Farmers received personalized advice on nutrient management for rice

- Results
  - Increases in yield = 7%, profits = 10%
  - Gains achieved *without an increase* in overall quantity of fertilizer used

Source: Arouna et al. (2021)

Innovations in risk management tools: indexed, smart-phone enabled insurance products

Lessons learned from 20 years of developing and testing insurance products

Feasible

- Insurance with low-cost, but high-quality indices such as area-yield indices, smart-phone pictures
- Bundling insurance:
  - Inputs, e.g. linking insurance with seed purchases
  - Insuring credit for on-farm investments
- Insuring cost of preventive investments (e.g. irrigation)
- Insuring remittances (insurance to migrants)

Less Feasible: market-based insurance of incomes/yields

Finance

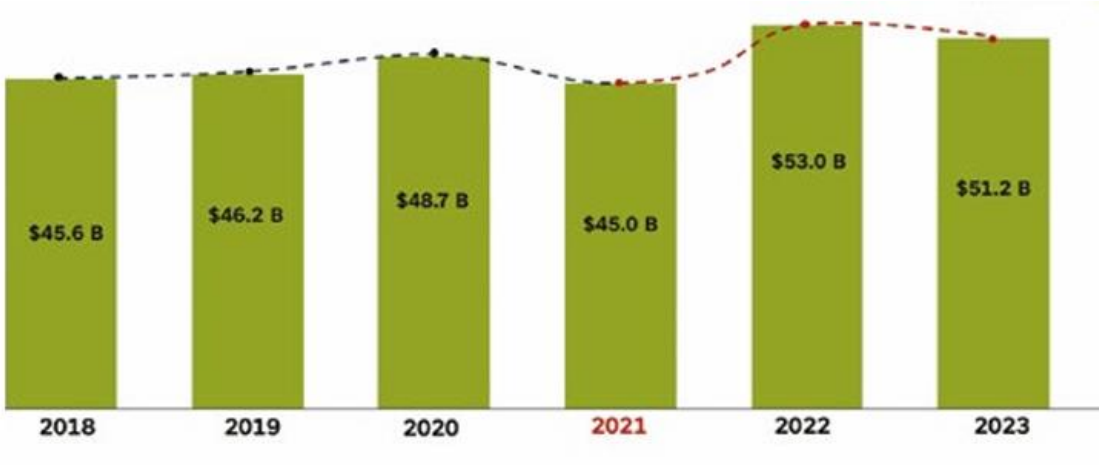
Financing

Public financing of RnD is declining, and public financing of investments in food systems

Policy reform and advice can help governments better spend existing resources

External development financial flows to food systems

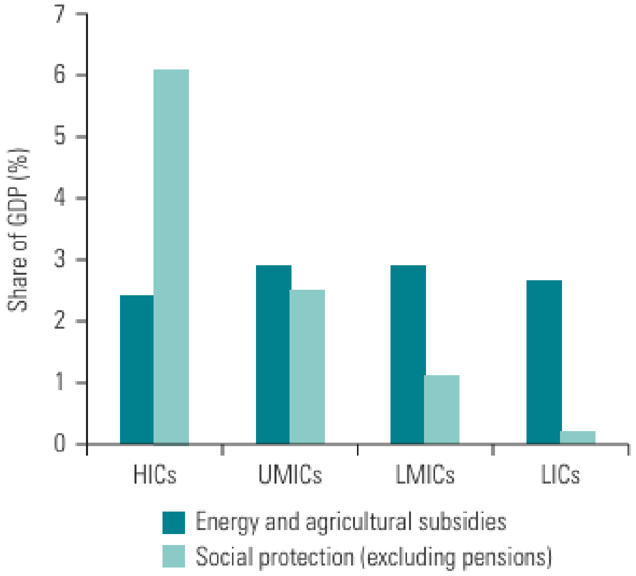
Stagnant in recent years and set to decline (US was the largest bilateral contributing 11 percent of external flows)



Source: Data accredited to OECD

Domestic producer support is 12x larger ($630 billion)

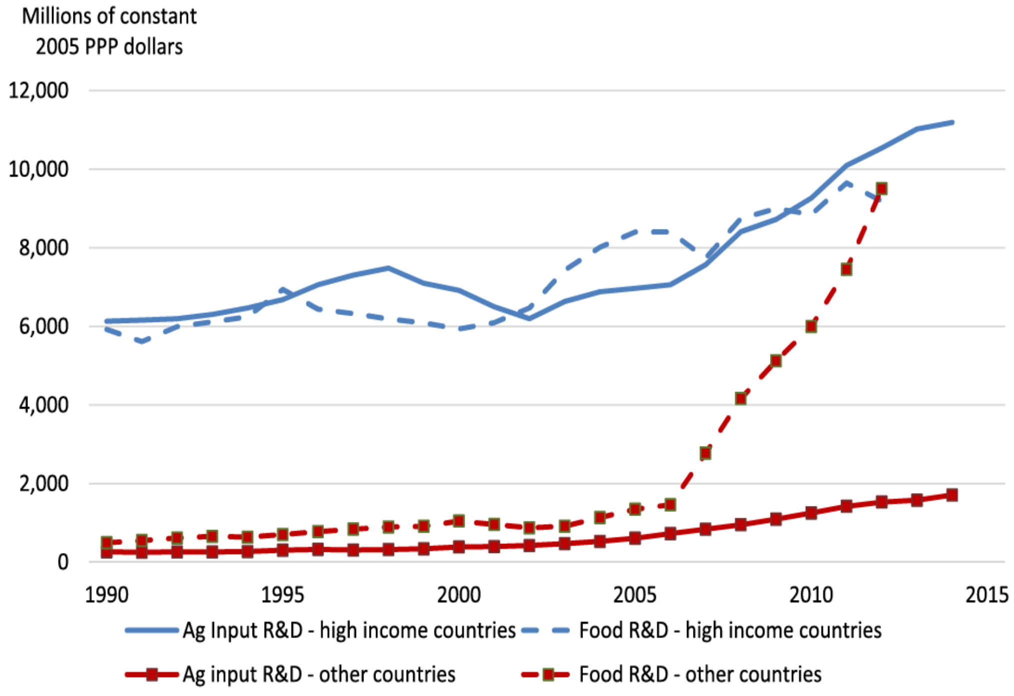
And widely present: structure of fiscal spending varies across income levels, but subsidy spending is constant



World Bank 2022. PSPR

Private sources of financing

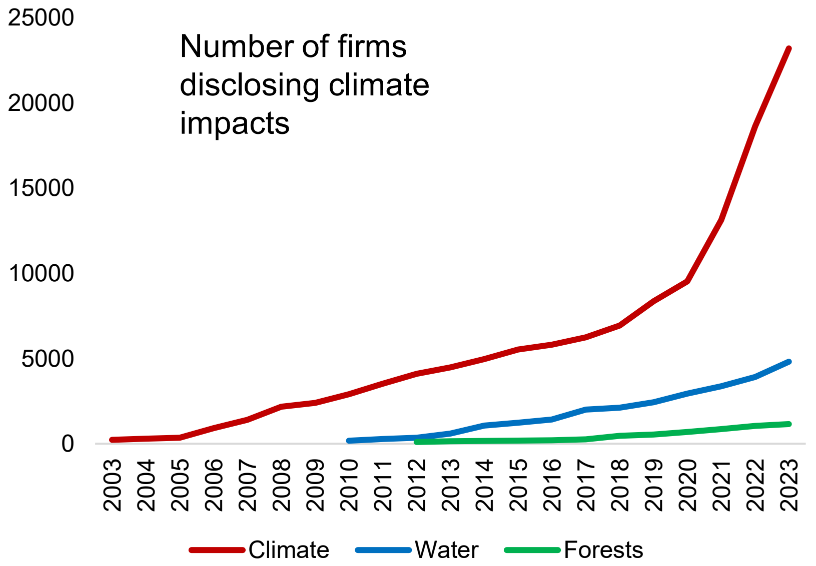
Private spending on ag RnD is increasing



Source: Swinnen using data from USDA

Increasing role for impact investors, voluntary carbon markets

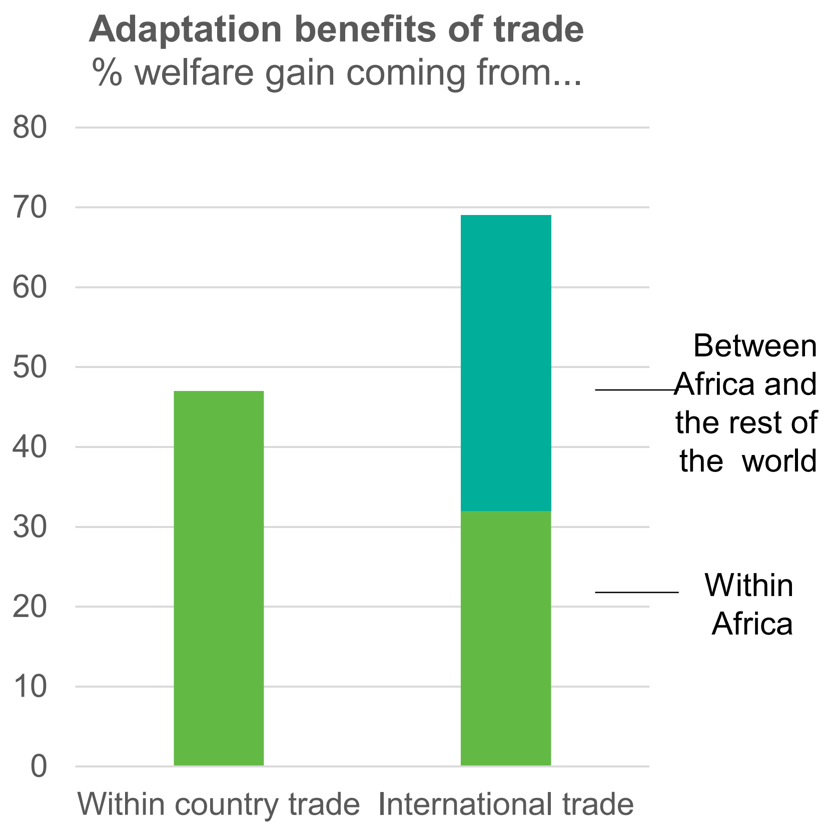
- Requires: reliable standards, better MRV, more information on bankable projects



CDP
DISCLOSURE INSIGHT ACTION

Trade

Lower trade costs are key to increasing production and reducing the impact of climate change



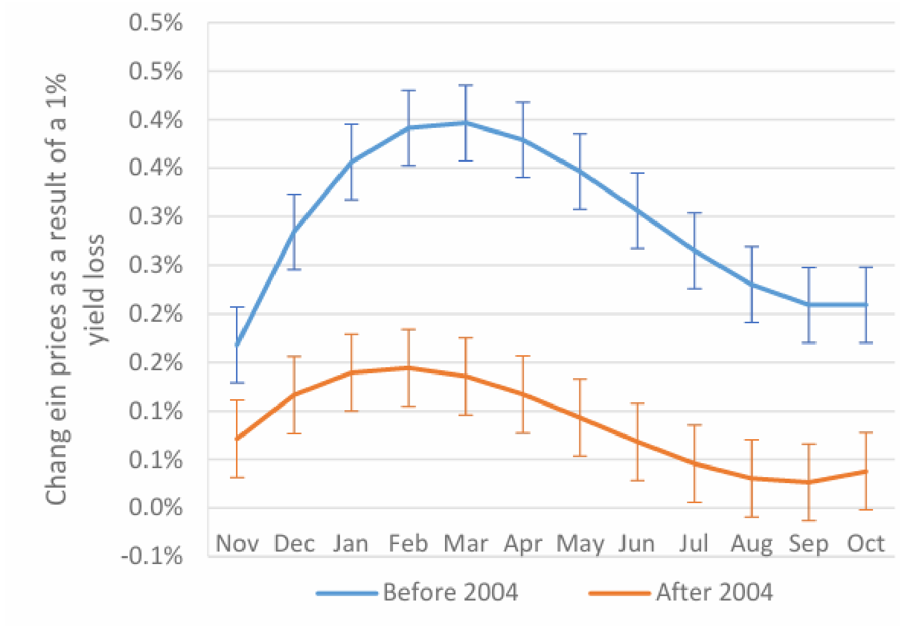
Porteous 2025

Sustainable agricultural production will involve producing food in the right places as weather patterns change, and trading efficiently and effectively to achieve national food security, not producing everything in each country.

Efficient food markets and trade reduce risk

Reducing trade costs also removes price risk.

Example: lowering trade costs in Ethiopia reduces the impact of weather shocks on local food prices.



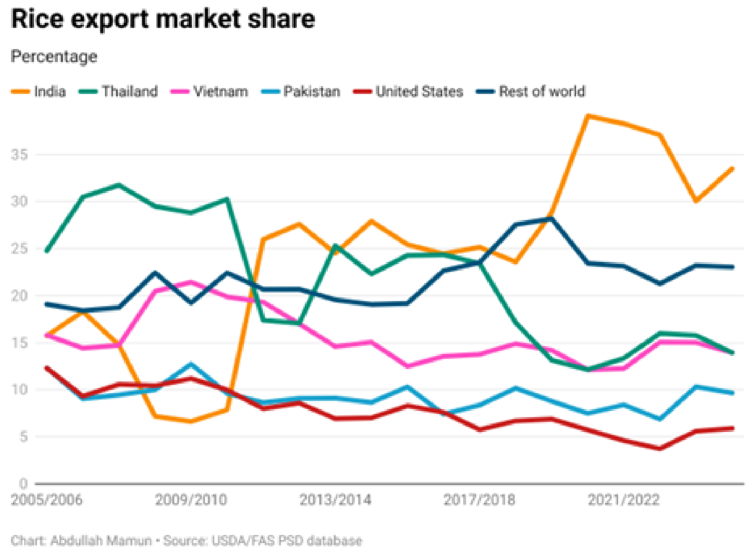
Hill and Fuje 2020

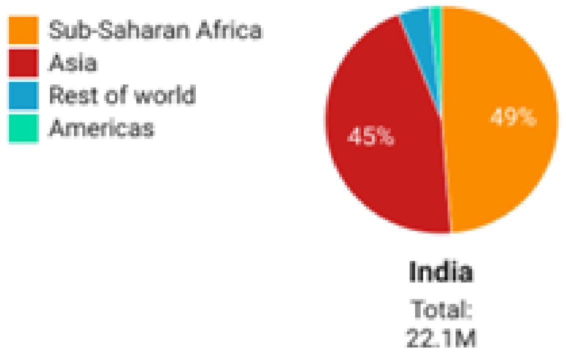
Trade policy: Producer support in large economies also shape incentives faced by farmers and consumers globally

Example:

- The global market for rice has become the most concentrated cereals markets in recent years: India has come to dominate rice exports, most going to Africa.
- This has been driven, in part, by large input subsidies to producers.
- This spending impacts the market for rice globally and the prices faced by farmers and consumers in other countries.

This is true for other large exporters of grains

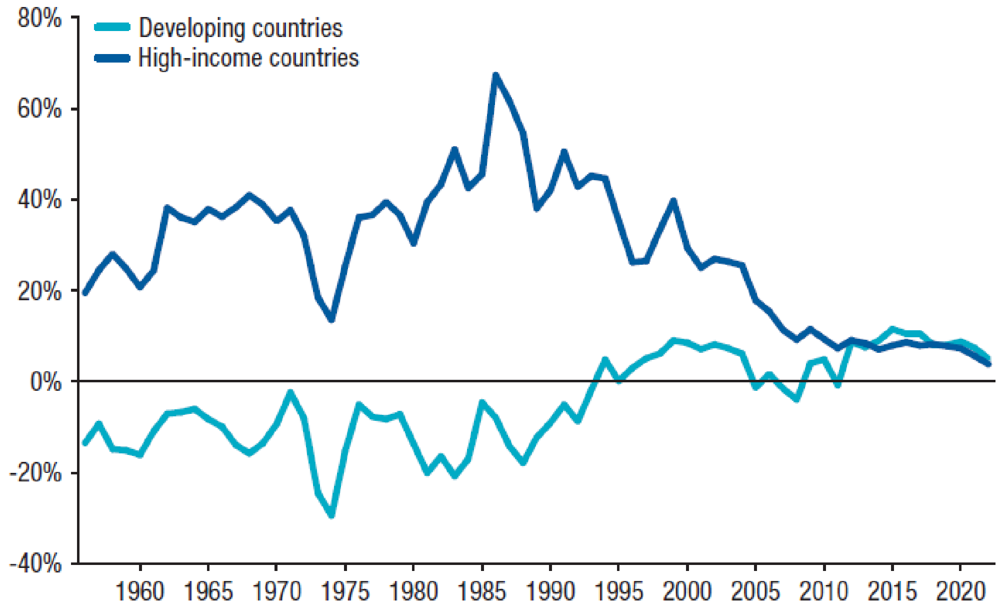




Glauber and Mamun. 2025

Overall policies have become less trade distorting

Domestic policies have become less trade distorting in high income and developing countries



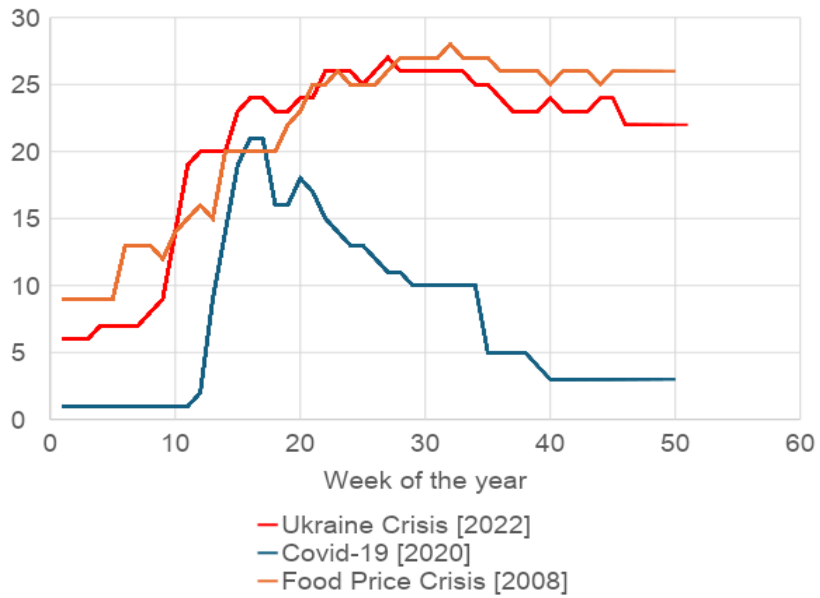
Source: AgIncentives Consortium database. www.agincentives.org

Note: Rates refer to the nominal rate of protection (NRP), as defined in footnote 2 to this chapter.

Further progress on trade needed for global food security

- Barriers to trade are still higher in the agricultural sector than any other sector and unstable (proliferation of export bans when food prices increase).

Number of countries implementing food export restrictions

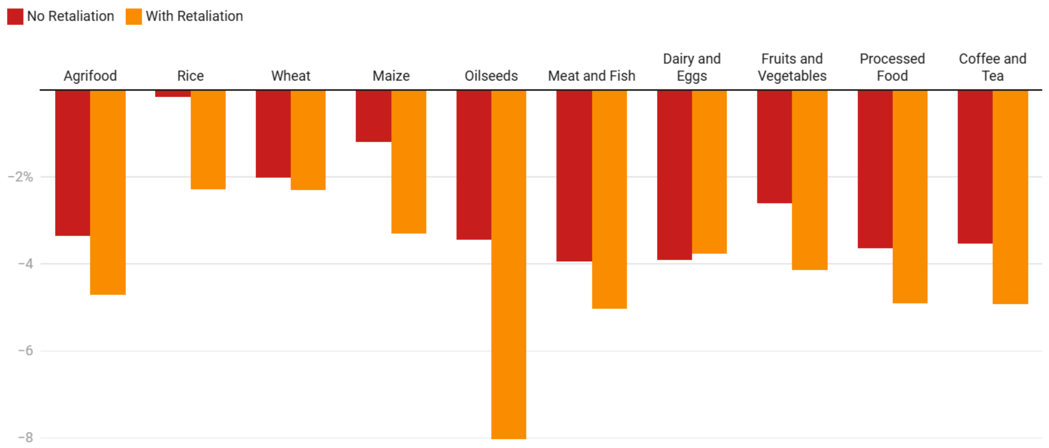


Source: IFPRI Food and Fertilizer Export Restriction Tracker 2023

- Recent tariff announcements have increased tariffs and we expect global agricultural trade to contract (April 2 simulation results)

Impact of reciprocal tariffs on global agricultural trade

Percentage change from baseline



Source: Calculations by authors based on MIRAGRODEP simulations. • Get the data • Download image

Sources: Glauber, Piñeiro and Gianatiempo (2025), Piñeiro, Gianatiempo, Traoré and Glauber (2025)

Lessons from trade shocks in recent years

Lessons from US-China soy and grain, Australia-China barley, Senegal-India rice, Egypt-Russia/Ukraine wheat

Four take-aways:

1. **Disruptions are costly** both for consumers (e.g. Senegal rice consumers, China soybean crushers, Egyptian wheat millers) and sellers (e.g. U.S. soybean exporters, Australia barley growers). In some cases governments have compensated.
2. **Global markets functioned well in providing alternative** supplies or alternative markets for their exports. In some cases countries have had to facilitate imports by approving phytosanitary protocols to accommodate new suppliers.
3. **Some countries have increased stocks** as a result or changed timing of buying patterns.
4. **Diversifying trade can be costly but less costly than self-sufficiency** strategies if the country is a high-cost producer.

Source: Glauber and Mamun 2025

Thank you!

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Underutilised Species Delivering Nutrition, Climate Resilience & Economic Value for sub-Saharan Africa

Prof. Jules Griffin, The Rowett Institute
& Sylvester Madzvova, CTDO Zimbabwe

Overview

- Estimating the Nutrient Value of Agricultural Products in Scotland
  - Benjamin McCormick
- Modelling UK and global seafood supply chains
  - Baukje de Roos and team
- Developing moringa as a nutritious and sustainable food in Malawi & Zimbabwe
  - Wendy Russell & Sylvester Madzvova

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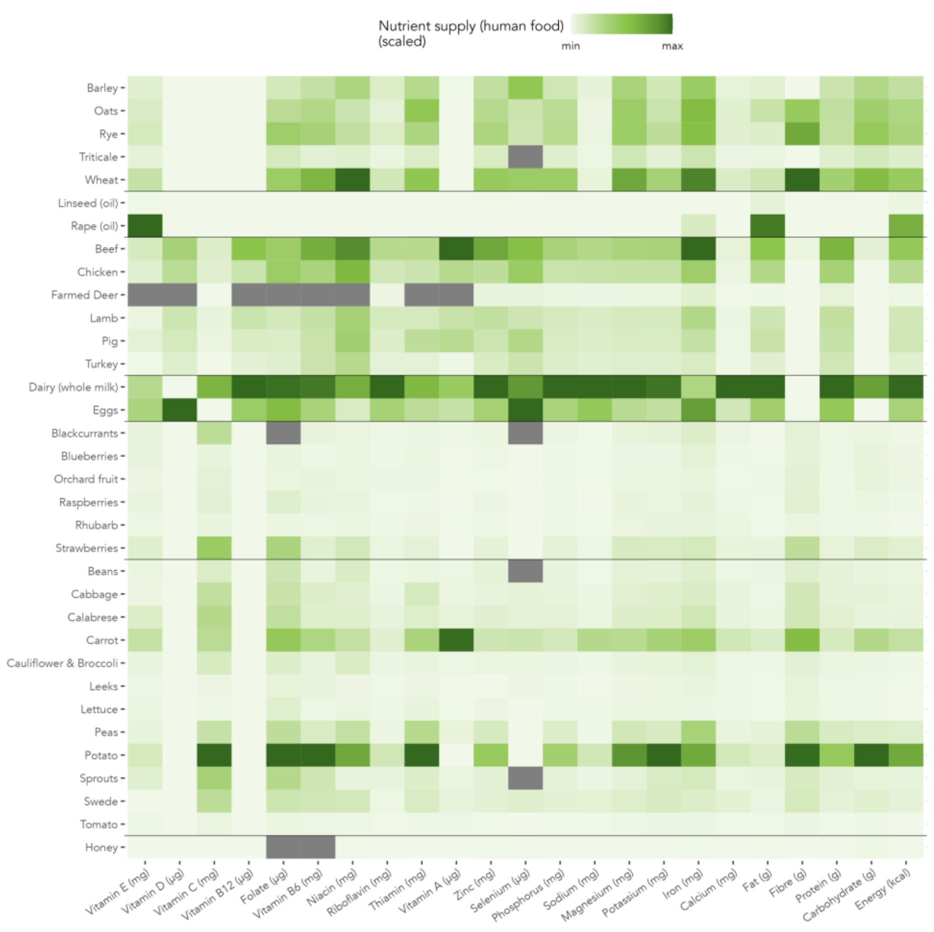
Benjamin McCormick

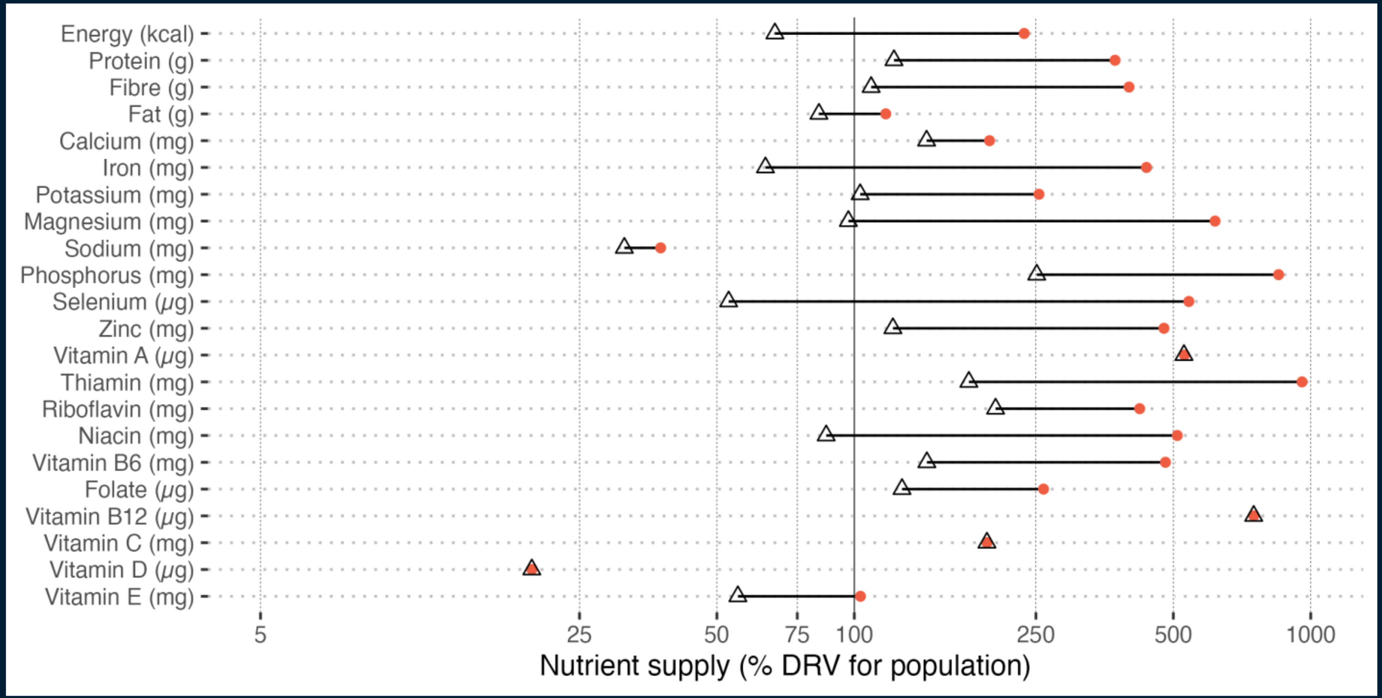
Estimating the Nutrient Value of Agricultural Products in Scotland



- SEFARI fellowship to "…contextualise the value of Scottish agriculture by estimating the supply of nutrients for human consumption."
    1. With increased pressure on the land (e.g. reforestation, wind and solar, etc) it's important to consider nutrient production as well economic worth
- Use June Agricultural Census and FAO Food Balance Sheets to estimate production of nutrients
    1. Grey missing data
    2. Note the importance of diary – nutrient dense and consumed in large volume
    3. While cereals are nutrient dense major proportion is not used for human consumption

What foods are important for nutritional security?

- Estimated nutrient supply of minimal processed commodities as a percentage of the whole population daily reference values.
- Model reductions in food commodities
    1. Meat would reduce certain nutrients but not ***on average*** below DRVs for any nutrients
    2. Eggs and dairy would reduce calcium, potassium, magnesium, zinc, riboflavin, niacin and folate below DRVs



Modelling UK and global seafood supply chains

Baukje de Roos

Most seafoods provide more nutrients than land-based protein alternatives, at lower emissions. Therefore, it is likely that seafood will feature more frequently in global diets as we transition to net zero.

nature food

Article https://doi.org/10.1038/s43016-024-01102-x

Seafood supply mapping reveals production and consumption mismatches and large dietary nutrient losses through exports in the United Kingdom

Received: 10 October 2023

Accepted: 27 November 2024

Anneli Löfstedt[1], Bernhard Scheliga[2], Magaly Aceves-Martins[1] & Baukje de Roos[1]

Rowett Institute of Nutrition and Health, University of Aberdeen · Scottish Government Riaghaltas na h-Alba, Marine Directorate · RESAS Rural & Environmental Science and Analytical Services · SEFARI · immana · DANIDA Danish International Development Agency · icddr,b

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Blue foods

https://doi.org/10.1038/s43016-023-00845-3

Integrated aquaculture–agriculture production supports food and nutrition security in Bangladesh

Baukje de Roos

Check for updates

Inadequate intakes of animal-derived foods, fruits and vegetables contribute to widespread malnutrition and nutritional deficiencies in Bangladesh. Combining aquatic food with crop production can maximize the nutritional and economic output of smallholder farms.

Aquatic food consumption is broadly beneficial for human health. Eating one or two portions of fish per week lowers the risk of heart disease and stroke[1]; therefore, many countries have food-based guidelines for fish consumption. For example, the United Kingdom only has two food-based dietary guidelines, and one of those two addresses fish intake. The health benefits of eating fish have traditionally been attributed to its levels of marine-derived omega-3 fatty acids, and higher circulating levels of these fatty acids in blood are associated with a lower risk of premature death from cardiovascular disease, cancer and other causes[2]. Fish consumption is thus particularly relevant for countries where the prevalence of such diseases mostly defines mortality rates. In low- and middle-income countries, however, aquatic food consumption is relevant for different reasons – here it substantially contributes to animal-derived protein intake and is commonly the only dietary source of some micronutrients. This is particularly relevant for Bangladesh, which has one of the worst global rates of malnutrition and nutritional deficiencies, mainly due to inadequate intakes of animal-derived foods, fruits and vegetables. Any changes to the supply of aquatic foods may therefore directly impact dietary quality and the nutritional status of its population[3].

Writing in *Nature Food*, Ignowski et al.[4] use a data-driven approach to explore the economic profitability and nutrient productivity of fish farms in Bangladesh that combine aquatic and terrestrial food production. The authors analysed data from a representative survey of 721 farms in southern Bangladesh, covering a variety of integrated aquaculture–agriculture practices, then combined data on the production of 35 aquatic and 31 terrestrial foods harvested from these farms over a period of approximately one year. They used food composition data to estimate the productivity per hectare of energy, protein and five key micronutrients: calcium, iron, zinc, vitamin A and vitamin B_{12}. Their approach represents a much-needed contextualization of integrated aquaculture–agriculture systems, aiming to maximize economic profits while simultaneously ensuring crop diversification and nutrient supply to support local and national food security.

At the global level, both small and large farms play key roles in providing food and nutrient security, but small farms, which are comparatively more abundant in Southeast and South Asia, often have a higher agricultural production diversity, as well as producing more protein and micronutrients[5]. Ignowski et al. found that the most profitable farming systems produced fish, prawn and shrimp with rice, vegetables and fruits (US$4,379 per hectare), and fish and prawn with rice, vegetables and fruits (US$3,947 per hectare). The latter farms also had the highest productivity of energy, protein, iron, zinc and vitamin A. Yet, economic productivity was partially disconnected from nutrient productivity: farming systems that included shrimp but did not integrate terrestrial foods had average economic productivity but much lower than average quantities of almost all nutrients per hectare[4].

nature food

- 2017-2019: Aquatic Food for Health and Nutrition project – Developing a metric for assessing the impacts on nutrition and health of agroecosystems producing farmed seafood (IMMANA)
- 2023-2028: AQUAFOOD project - Climate resilient aquatic food systems for healthy lives of young women and girls in Bangladesh (DANIDA)

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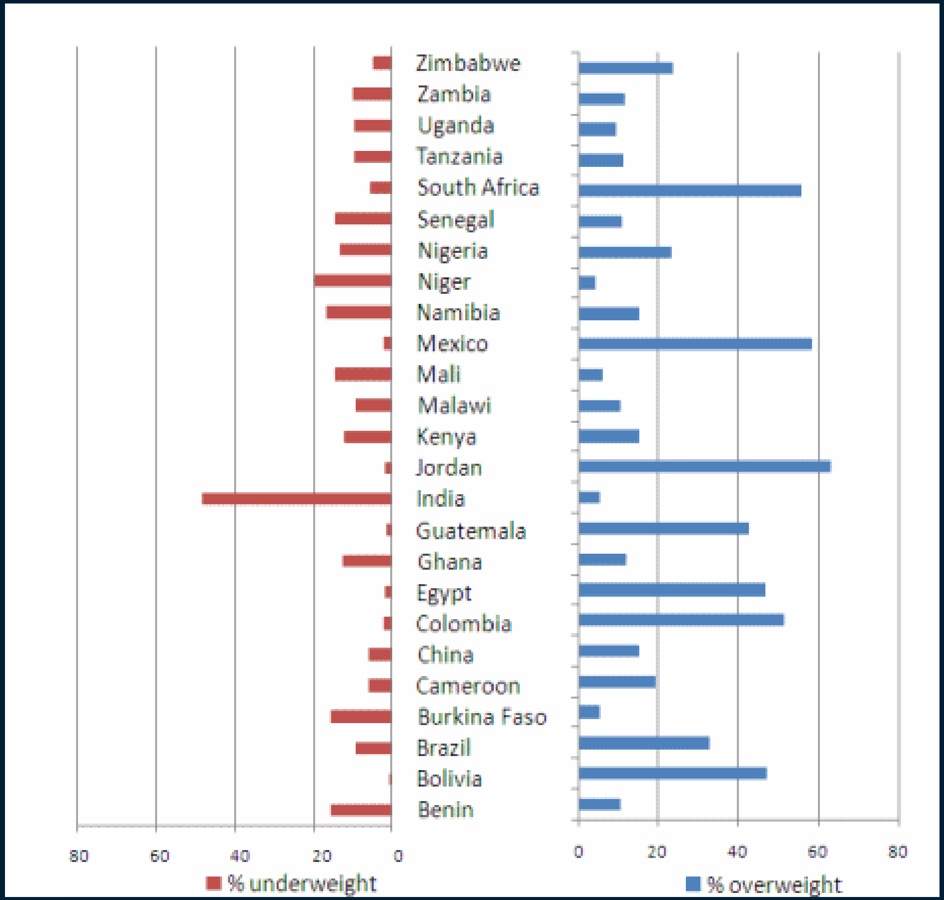
Food Security in Malawi



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Sylvester Mazvova
Madalina Neascu
Dinka Rees
Wendy Russell

Moringa; delivering nutrition and economic value to the people of Malawi

Department for International Development

'to be successful, agriculture will have to change
to a more dynamic model that will open up new opportunities for commercialisation'

This Project:

- focus on one neglected and underutilised species; moringa
- potential to contribute to Malawi's scaled-up nutrition programs
- commercialisation opportunities (protein provision and nutraceuticals)

GCRF Global Challenges Research Fund
BBSRC bioscience for the future

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Crop Variation - Macronutrients

- Compared protein, total fat, fibre, individual fatty acids, vitamins, minerals & phytochemicals for 3 sites across Malawi – Llongwe, Salima & Chikwawa

%	Lilongwe	Salima	Chikwawa
dry matter	94.32 ± 0.02^{a}	95.10 ± 0.05^{b}	95.25 ± 0.02^{c}
ash	11.42 ± 0.08^{b}	14.05 ± 0.06^{c}	10.25 ± 0.02^{a}
protein	$28.24 \pm 0,27^{b}$	28.57 ± 0.04^{c}	27.15 ± 0.05^{a}
total fat	6.25 ± 0.07^{a}	6.86 ± 0.28^{b}	6.43 ± 0.18^{a}
resistant starch	n/d	n/d	n/d
insoluble fibre	9.03 ± 0.36^{a}	11.67 ± 0.33^{b}	14.26 ± 0.55^{c}
soluble fibre	0.81 ± 0.03^{c}	0.34 ± 0.01^{b}	0.26 ± 0.01^{a}

Reformulation of WFP Supplement

	SUPER CEREAL plus	Moringa
maize	58.3	58.3
soya (de-hulled)	20	-
milk powder (skimmed)	8	8
sugar	9	9
soya bean oil	3	-
vitamin/mineral premix	0.2	-
dicalcium phosphate	1.23	-
potassium chloride	0.27	-
moringa	-	20

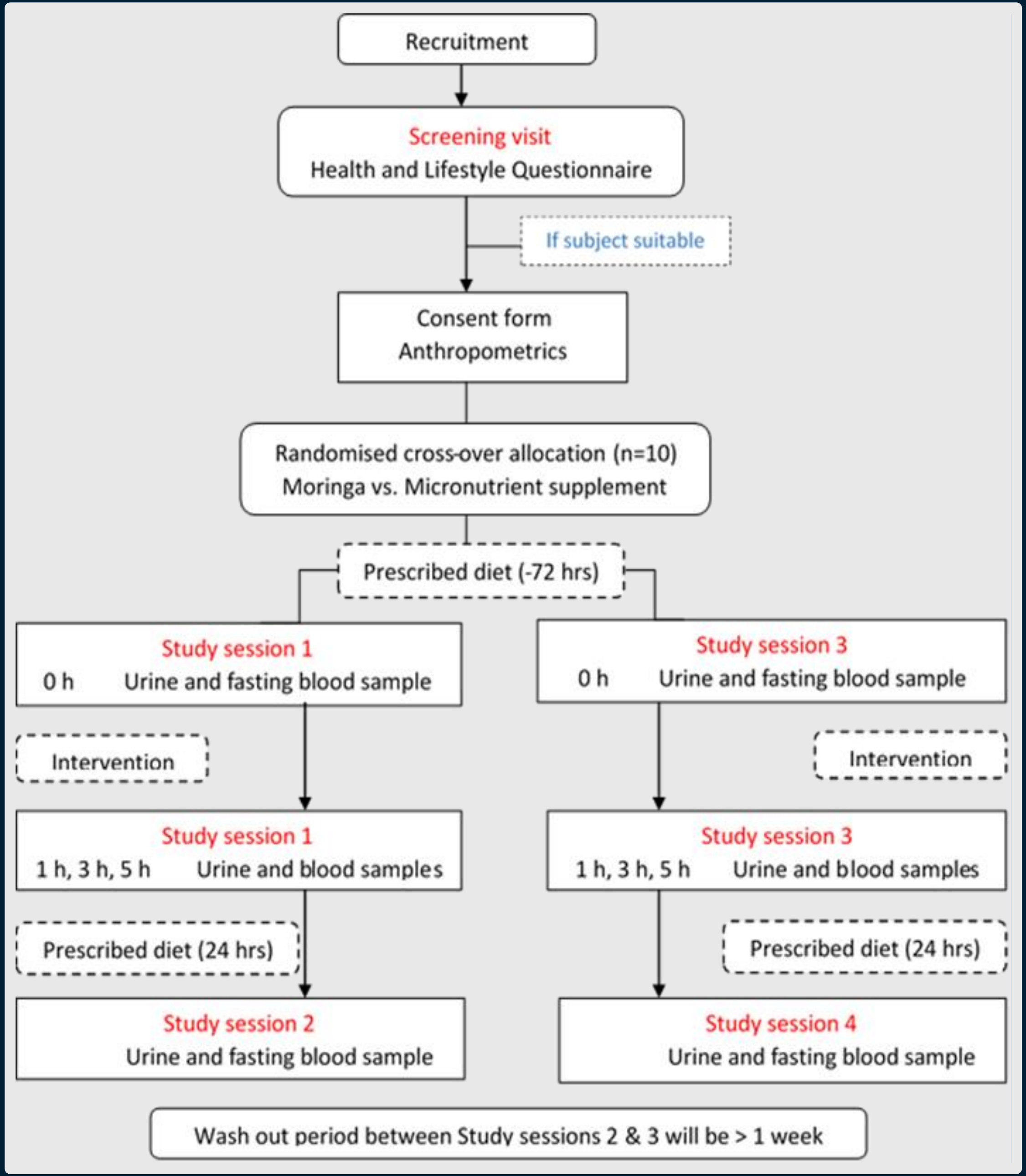
Human Study

Malnutrition

- protein replacement (amino acid profile)
- micronutrient content and bioavailability

NCDs

- bioactive phytochemicals



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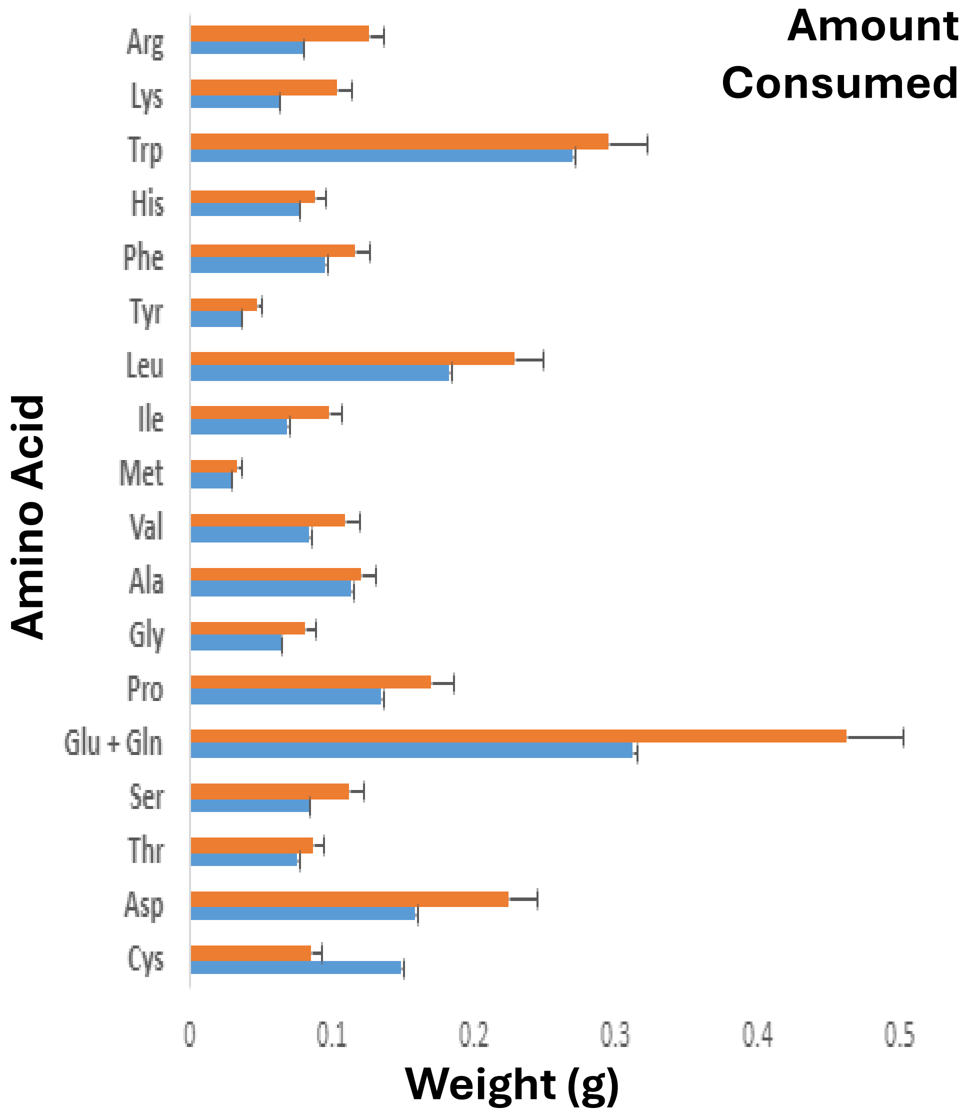
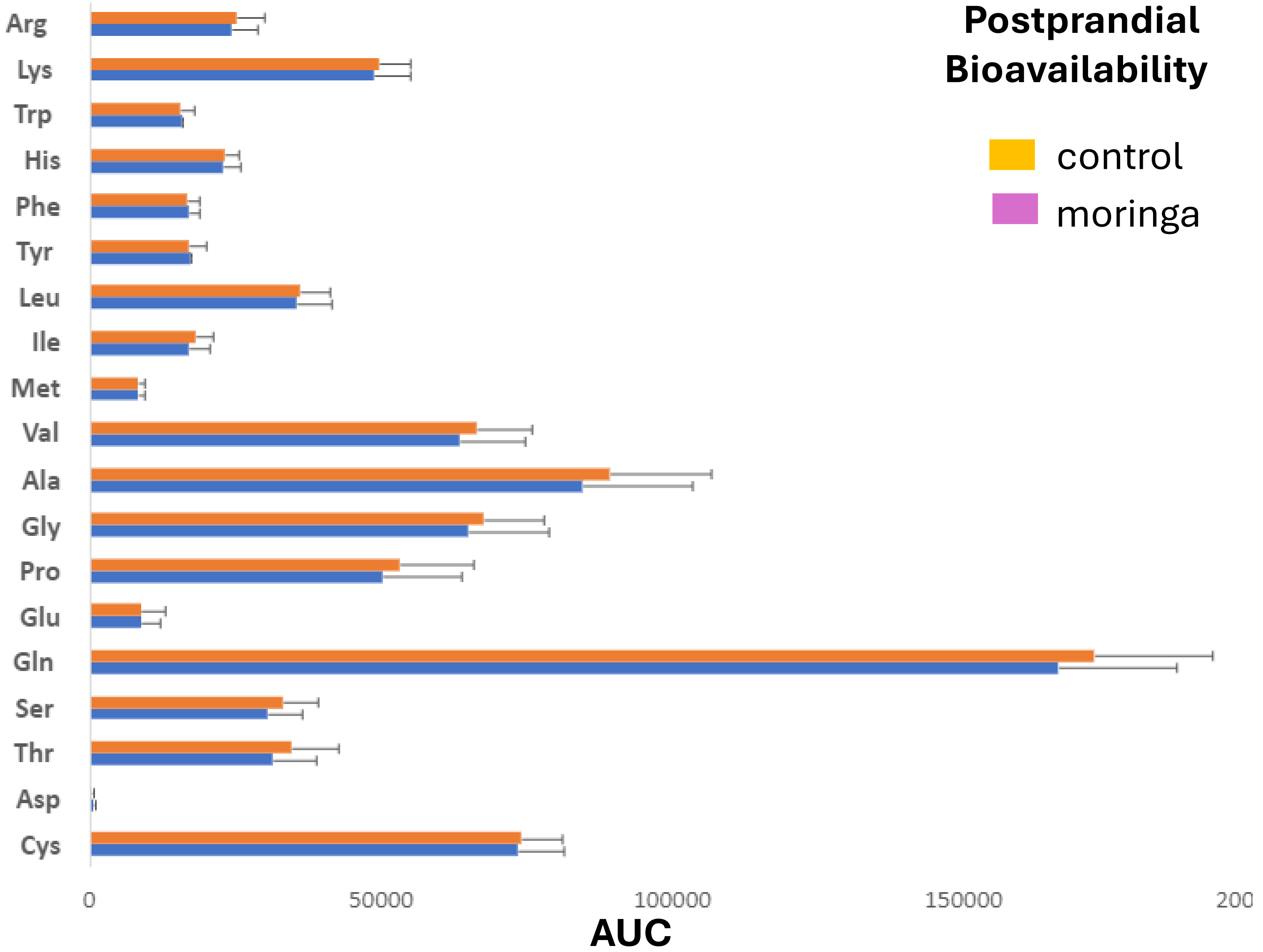
Amino Acid Profile





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EDINBURGH | 5-7 NOVEMBER 2025
GLOBAL FOOD SECURITY: CLIMATE CHANGE, COLLABORATION, AND COMPARATIVE ADVANTAGE

Scottish Government
Riaghaltas na h-Alba

SEFARI Gateway

Summary results

Potential for moringa to replace soya protein

- higher amount required for young children
- improved in terms of AA profile (cys & BCAAs)

Moringa can partially replace the micronutrient premix

- higher in Na, Mg, Ca, Mn, Fe and Co
- lower in P, K, Cu, Zn and Mo

Few phytochemical differences (soya vs moringa)

- soya meal significantly higher in phytoestrogens
- moringa higher in several phenolics
- moringa higher in indole-3-carboxylic acid

Moringa appears beneficial for gut health

- increased SCFAs, phenolic metabolites, indole-3-propionic/carboxylic acid , enterodiol

In-Country Engagement

COMMUNITY TECHNOLOGY DEVELOPMENT TRUST

Workshop attended by a wide range of stakeholders, including the Ministry of Agriculture, WFP, ICRISAT, Oxfam, academics and private sector actors

- National Strategy and Action Plan for Plant Genetic Resources for Food and Agriculture
- Small Grain Policy

"SEFARI scientists played a fundamental role to kick start the process of reviewing and formulating the two policies above as a strategy to strengthen the conservation and promote the sustainable use of plant genetic resources for food and agriculture"

– Andrew Mushita (Executive Director; CTDO)

"working in farmer field school groups is empowering as we can exchange seeds, recipes and knowledge on how to grow and conserve NUS and other local plant resources important for food and nutrition"

Gladys Chiunye, Edina Kawiwi and Sophia Chari

"NUS are important as they provide nutritious dishes especially during the dry months of year and also in drought years"

Netsai Silli & Rugare Munazi

"drying indigenous vegetables lessens women's challenges of looking for them, especially during the dry months of August to November"

Ellah Chipetekure

"seed fairs have enabled us as farmers to exchange, share, trade as well as creating market linkages to improve the availability of locally produced seed"

Smolly Ndlovu & Dadirai Musona

"traditional seed varieties had disappeared at an alarming rate but through the various programs that CTDO and partners are implementing we have managed to conserve our genetic diversity"

Abigirl Chimimba

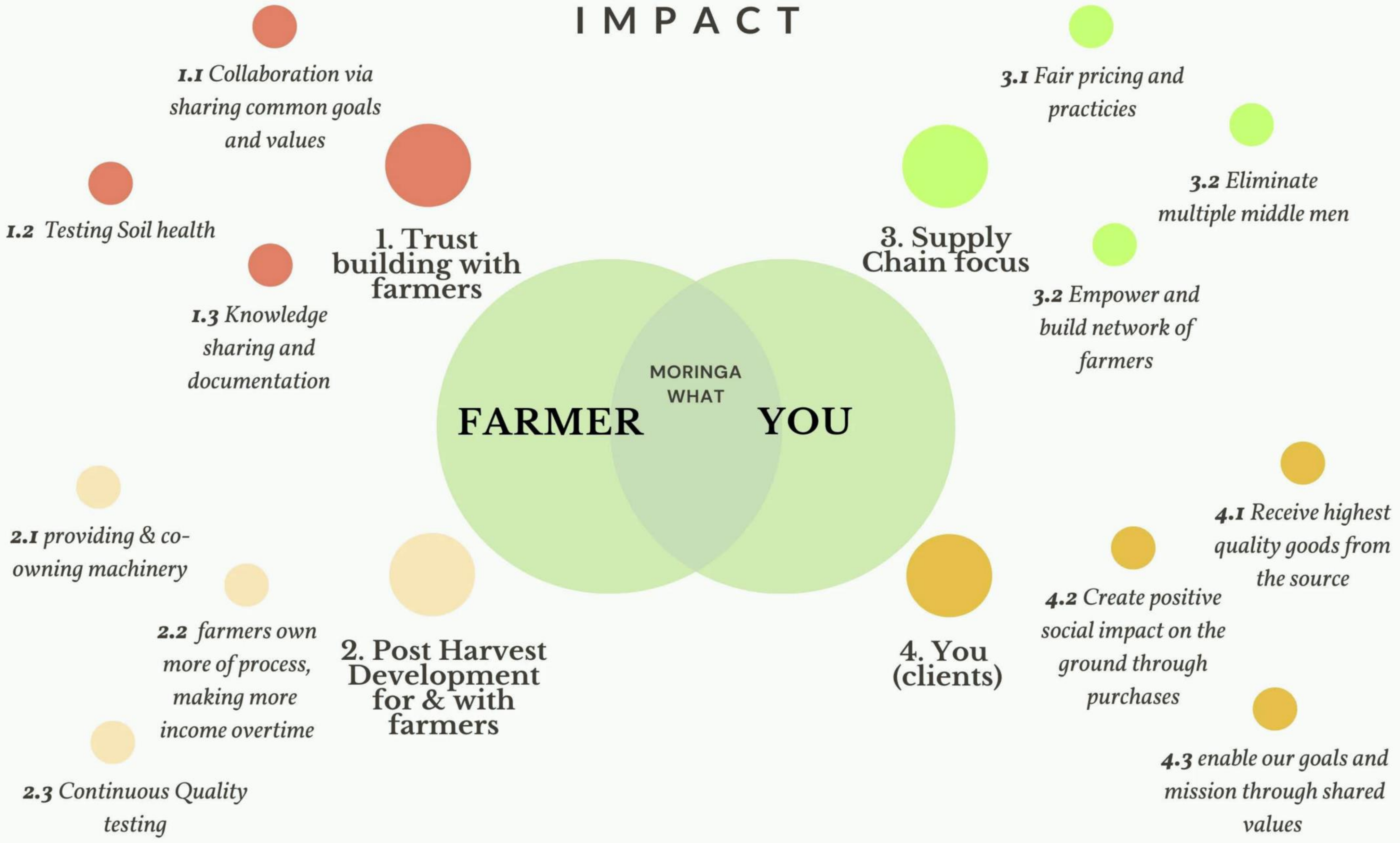
"crop diversification is key to improving household nutrition"

Jennifer Bhero

Economic benefits of effective Collaboration

Sylvester Madzvova, CTDO Zimbabwe

CIRCLE OF IMPACT



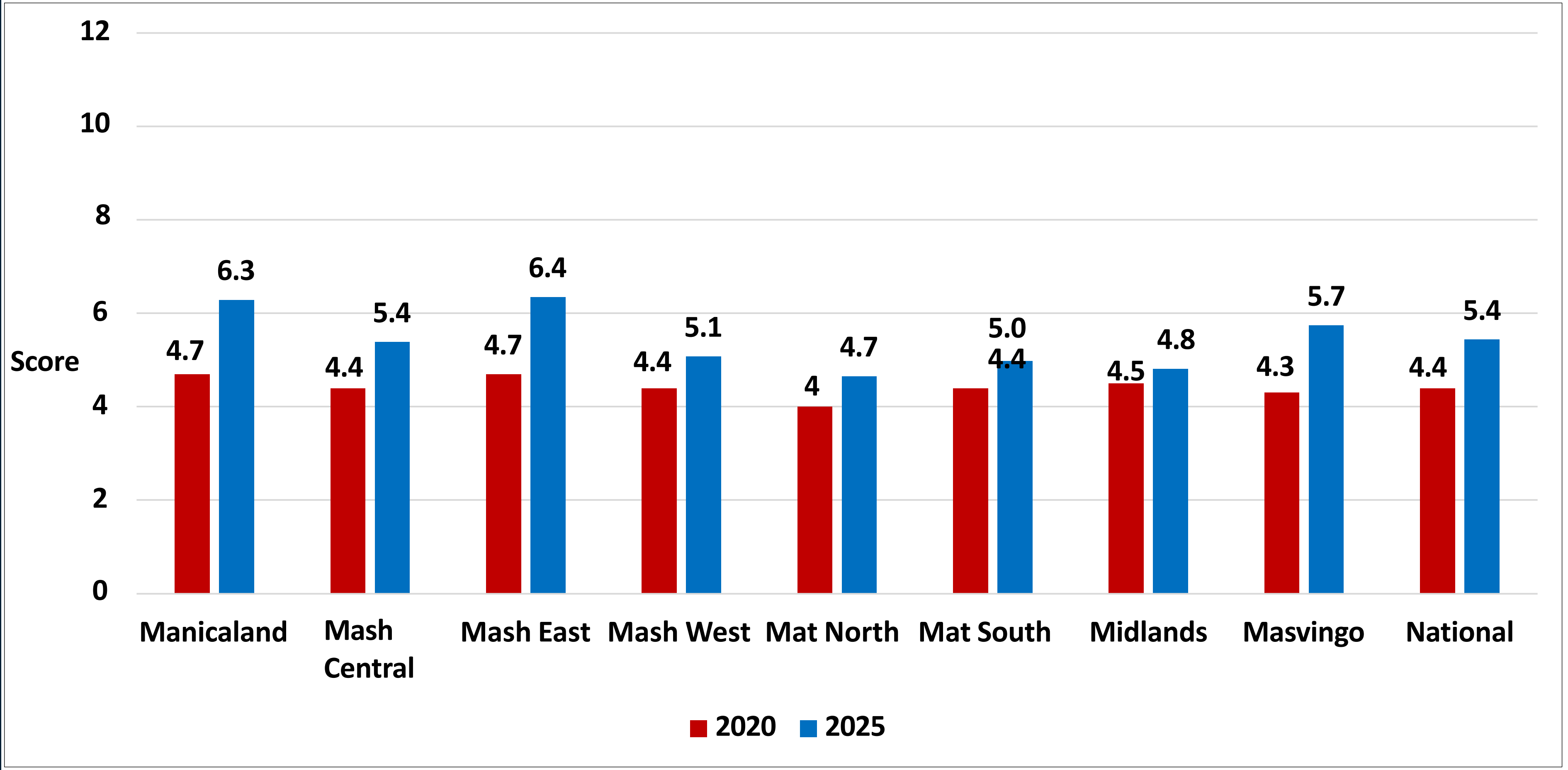
Commercialisation – Value Chain

Price component	Share in %
Exporter	5
Importer in Transit Country	10
Import Tariff	0
Importer in End Market	10
Packer and Distributor	20
Online Retailer	49
VAT (6%)	6

Retail Price 30-135 Euro/Kg

Sciiona - Next Generation Moringa. At last, no more bitter-tasting moringa. - YouTube

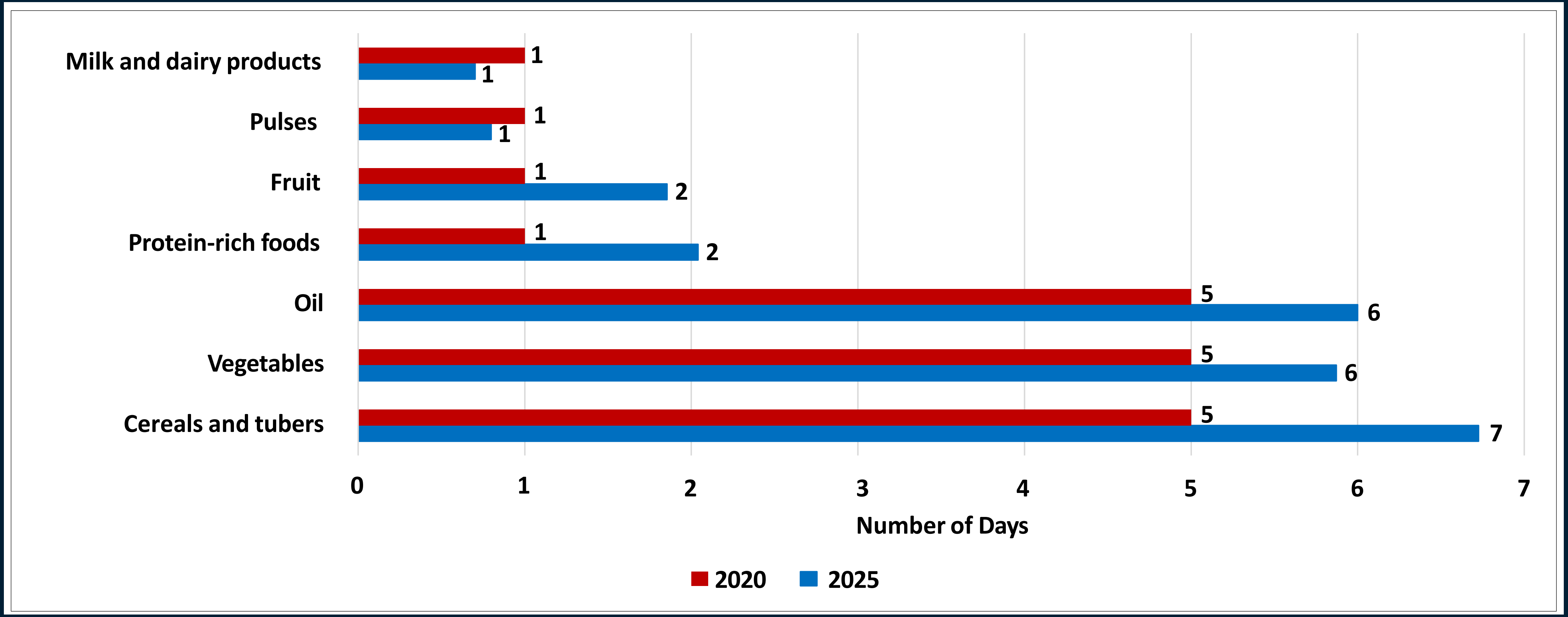
Average Household Dietary Diversity Score



- Improvements in the dietary diversity score from 4.4 in 2020 to 5.4 in 2025

Source: ZimLac Rural Livelihood Report 2025

Average Number of Days Households Consumed Food from the Various Food Groups

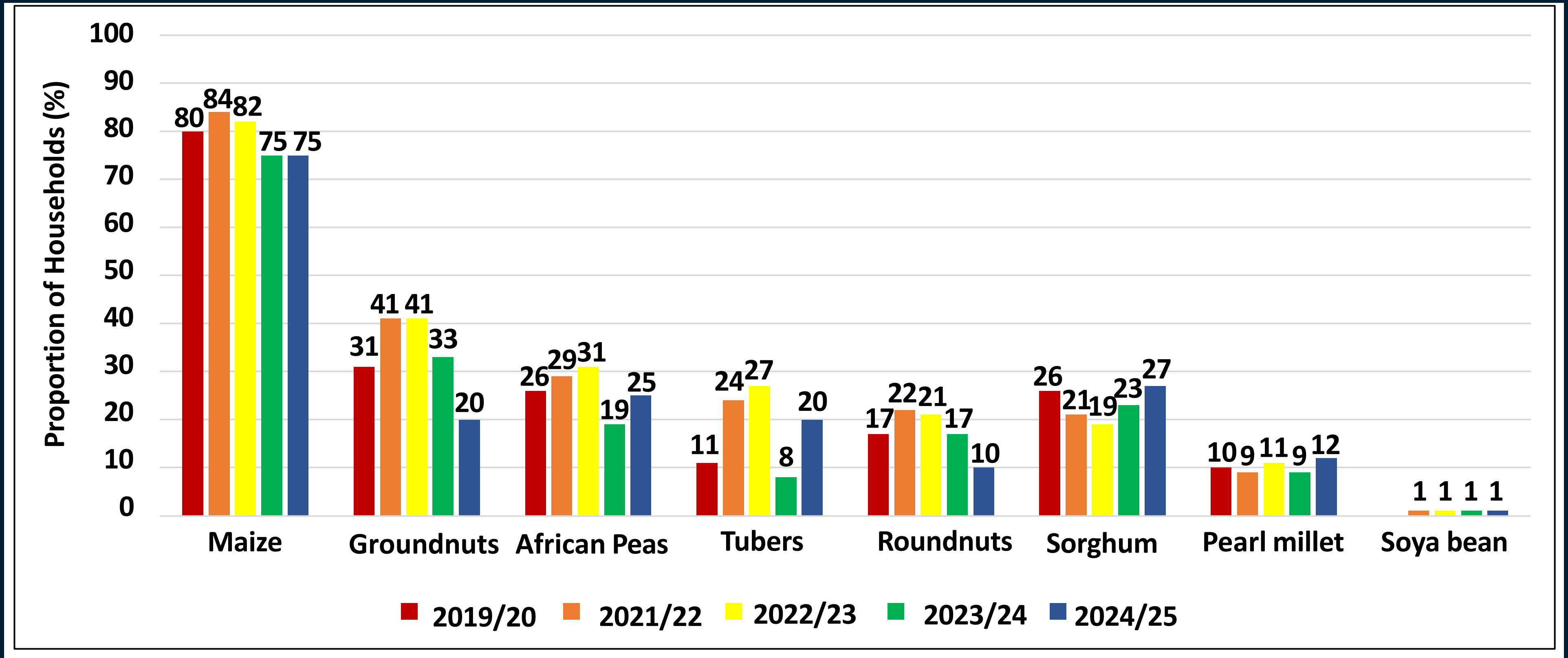


- Marked increase in cereal consumption including amog others small grains.

- Marked increase in cereal consumption including among others small grains.

Source: ZimLac Rural Livelihood Report 2025

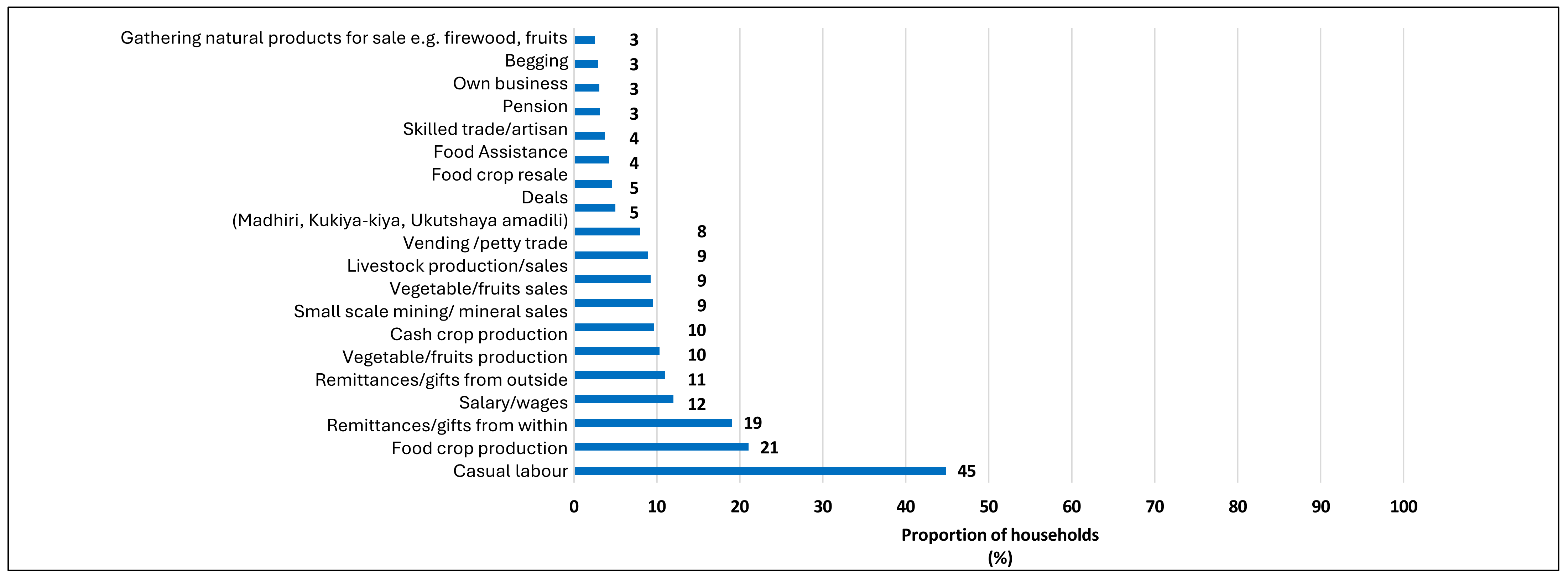
Crops Grown by Households



- The proportion of households which grew crops increased for African peas, tubers, pearl millet and sorghum.
- The proportion of households which grew maize remained the same (75%).

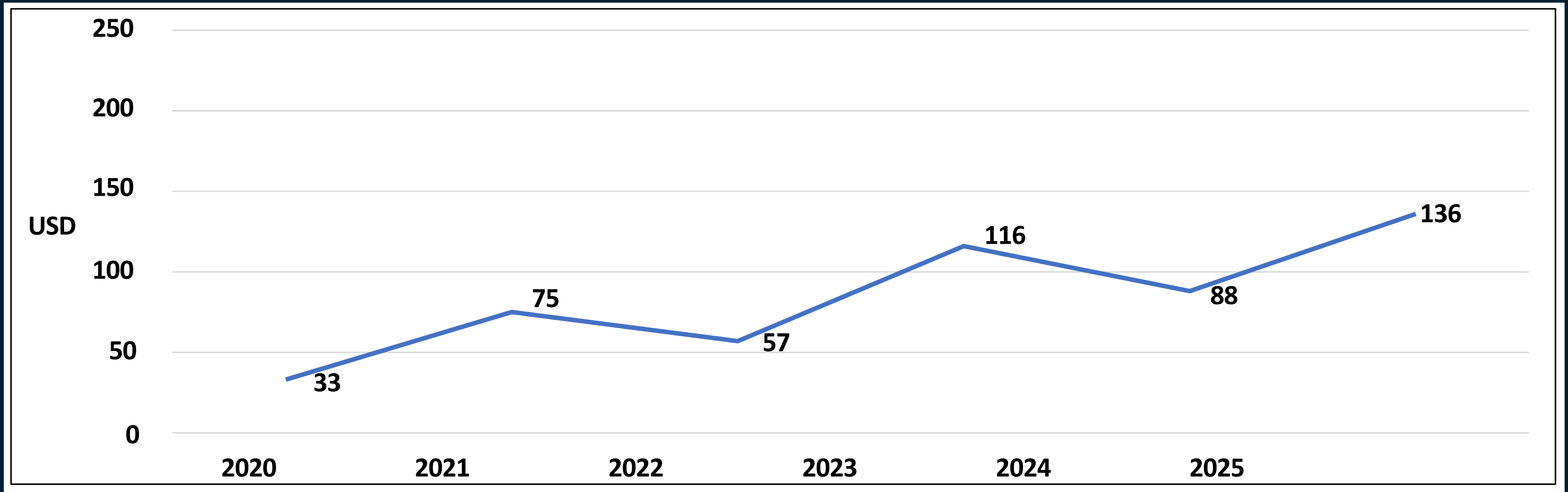
Source: ZimLac Rural Livelihood Report 2025

Household Main Income Sources



- The share of gathering and crop production is evidently a critical component of household income at national level
- Fair pricing, training, mechanisation and change of mindset will increase the share and increase per capita income

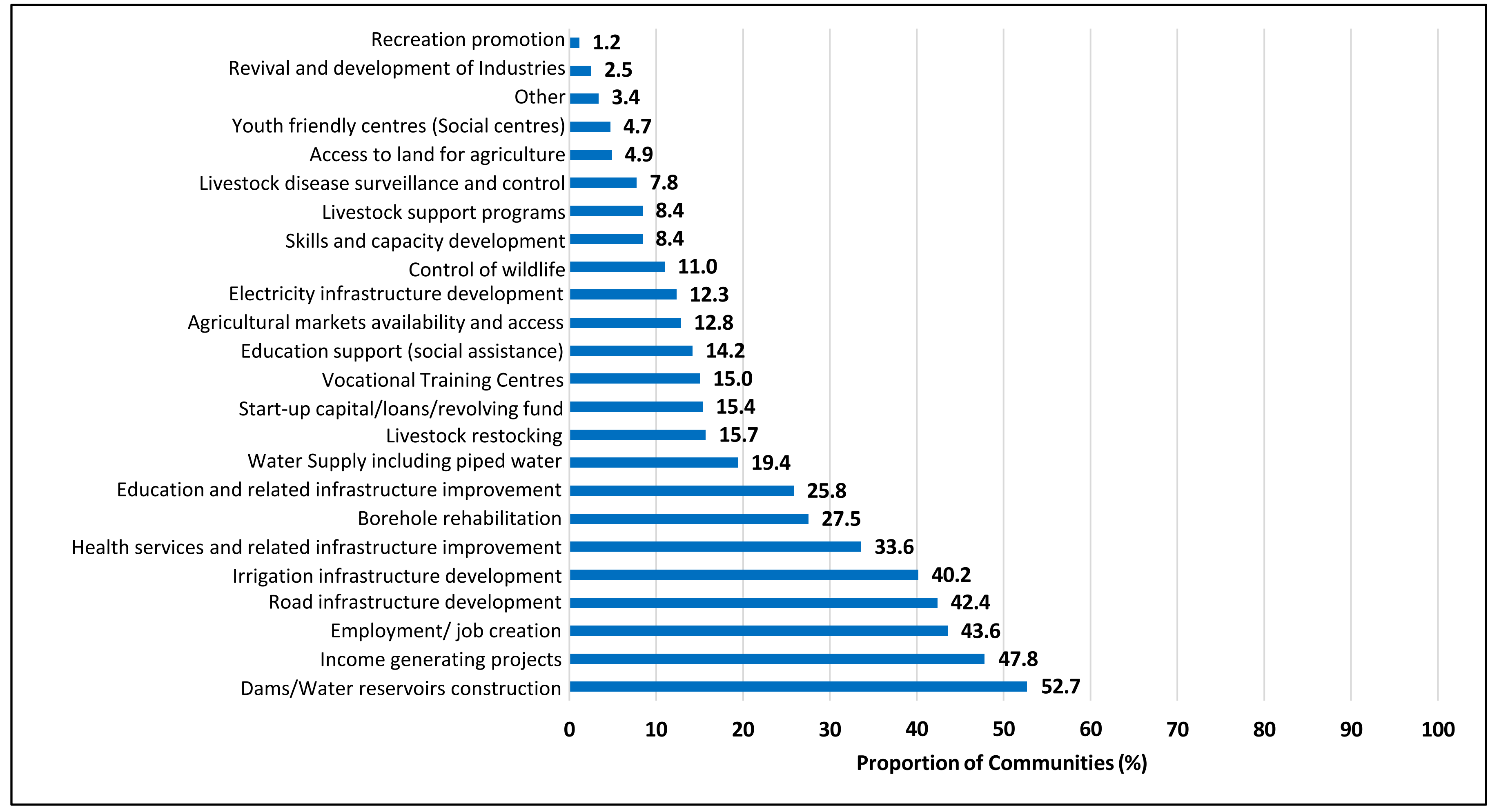
Income Trends (USD): 2020-2025



- Increased Rural Income with a high positive increase in disposable income.
- This is expected to continue contributing to a higher material quality of life, broadly contributing to increased consumer spending, economic growth, higher savings and investments, improved standard of living and reduced inequality.

Challenges and Opportunities for Future Collaboration

Community Development Priorities



- Agricultural Markets availability and access - 14.2%
- Skills and capacity building + Education 26%

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Adapting crops for climate change - technological and social innovation

Colin Campbell, CEO – The James Hutton Institute
& Ian Barker, Board Director - CGIAR UK.

Key messages

- The Hutton partners worldwide, locally and in-country partners are key
- Globally, and regionally, crop comparative advantage will change
- New plant science technologies have potential to speed our adaptation and address the un-precedented change we face
- Combining natural and social sciences in inter-disciplinary approaches is the most effective way to find socio-technological solutions
- Done properly food security can spare land and tackle biodiversity loss
- Potatoes are FANTASTIC and have huge potential to address Global food security

The James Hutton Institute collaborates and works in numerous global locations, exporting and importing knowledge, impact, innovation, skills, learning and experience.

Our
Impact

From Scotland to the world and back!

We collaborate with >35 countries World-wide

For every £1 of SGOV funding we give back £15 to the UK economy

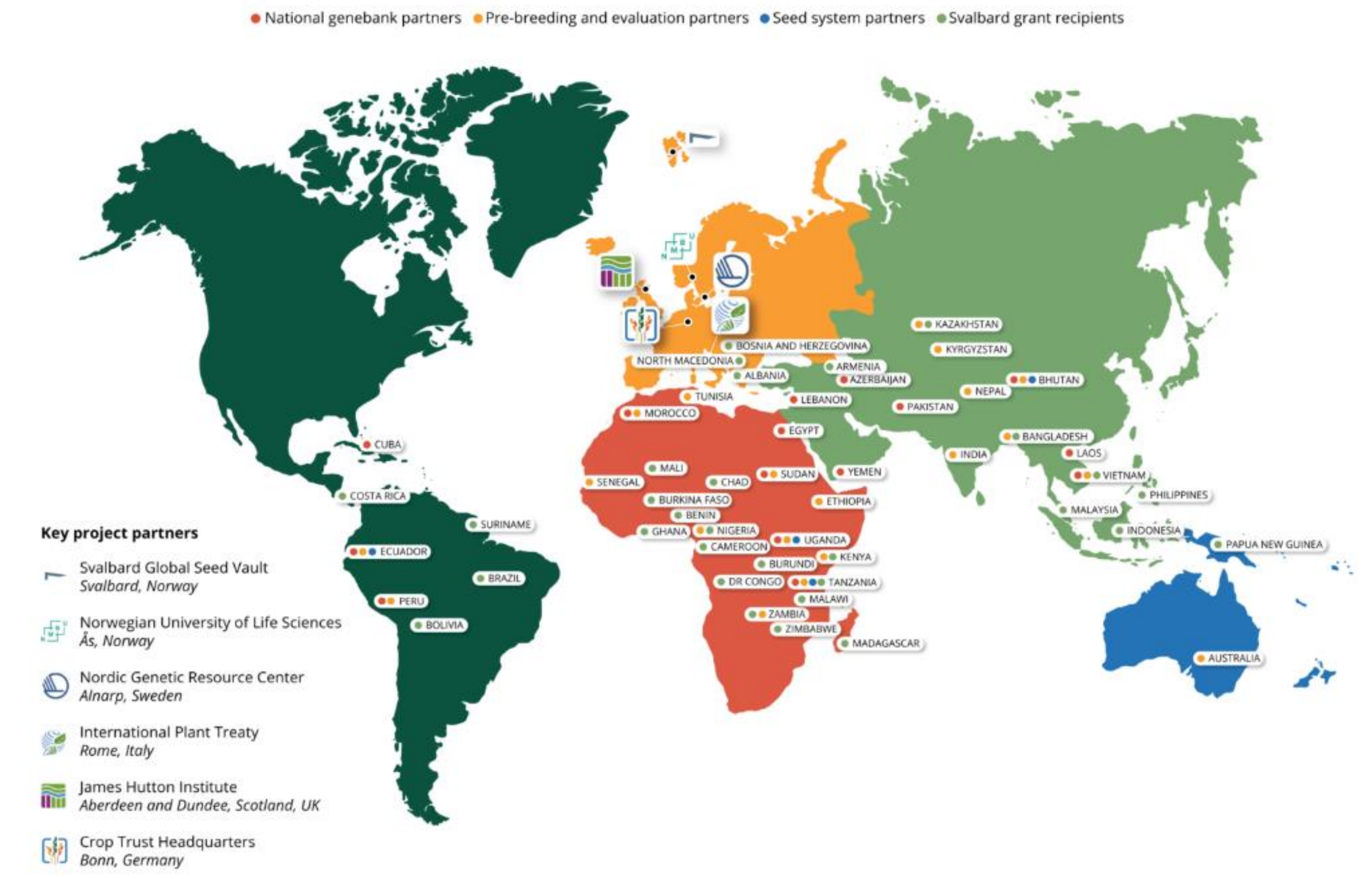
BOLD - Biodiversity for Opportunities, Livelihoods & Development

- 10-year project to strengthen food and nutrition security worldwide by supporting the conservation and use of crop diversity.
- Hutton bioinformatics and data analytics are a key tool being used for many crops worldwide.

CROP TRUST
[The BOLD project]

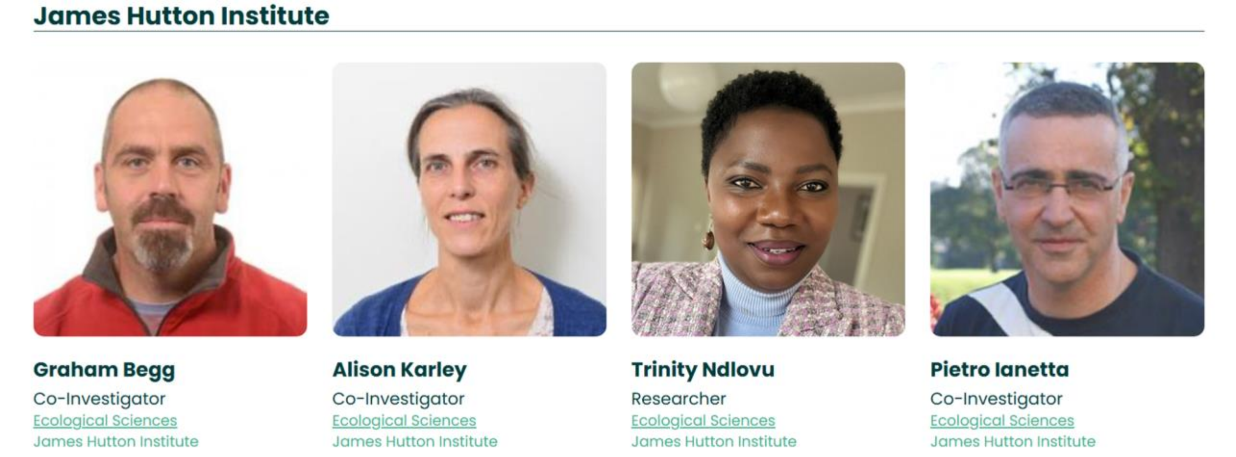
The James Hutton Institute

BOLD Partners and Activities

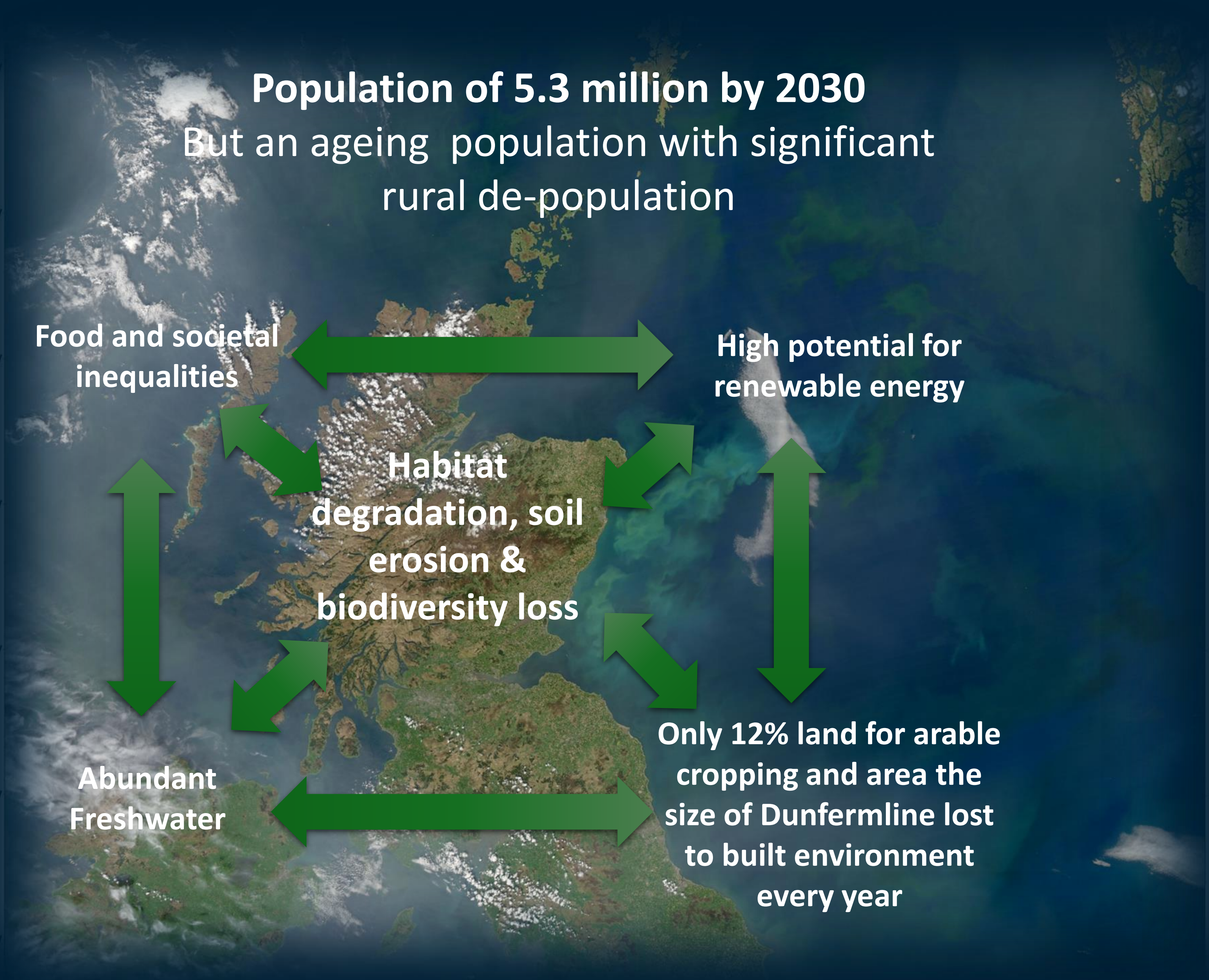


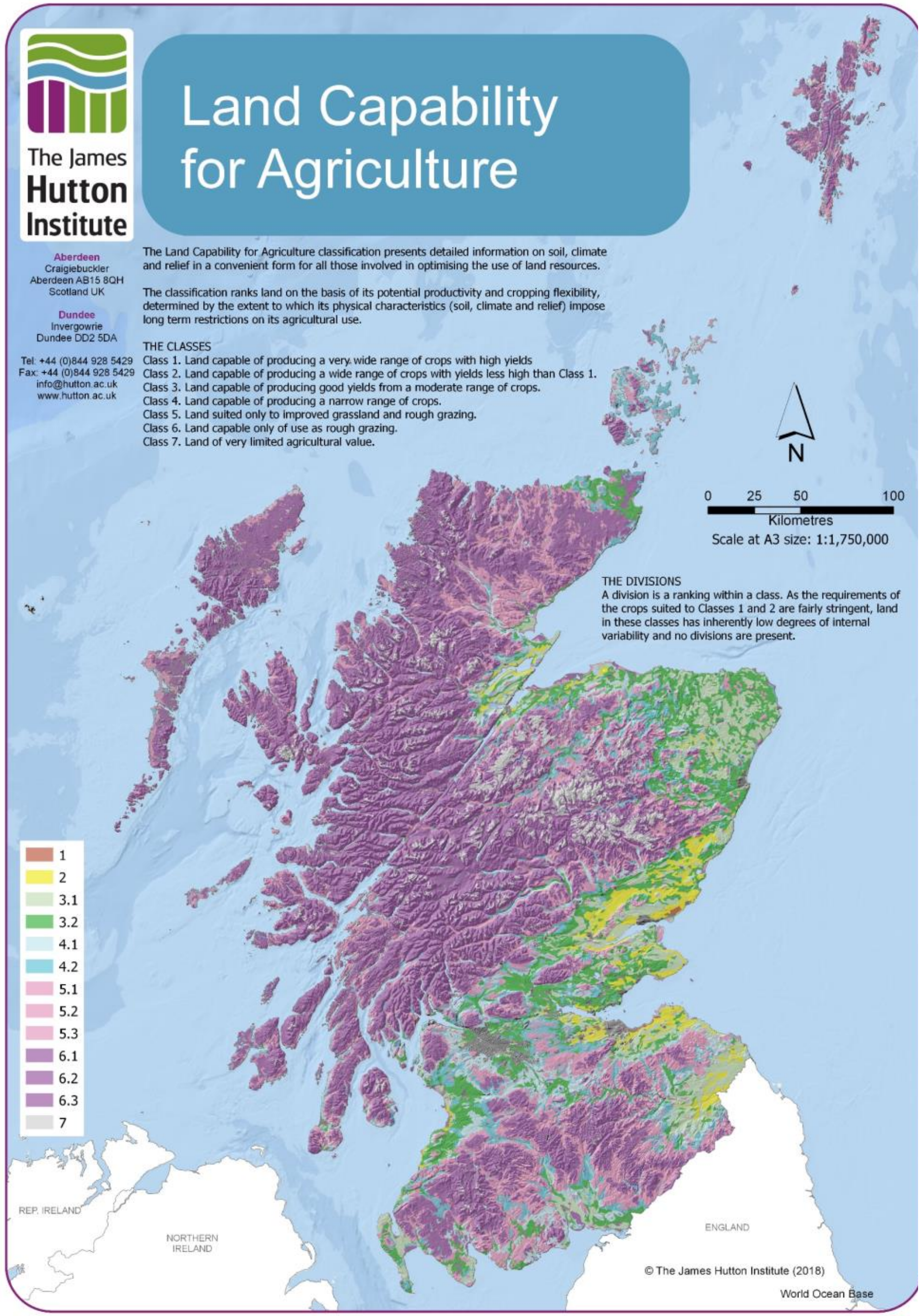
Island communities in South Pacific, Caribbean and Philippines

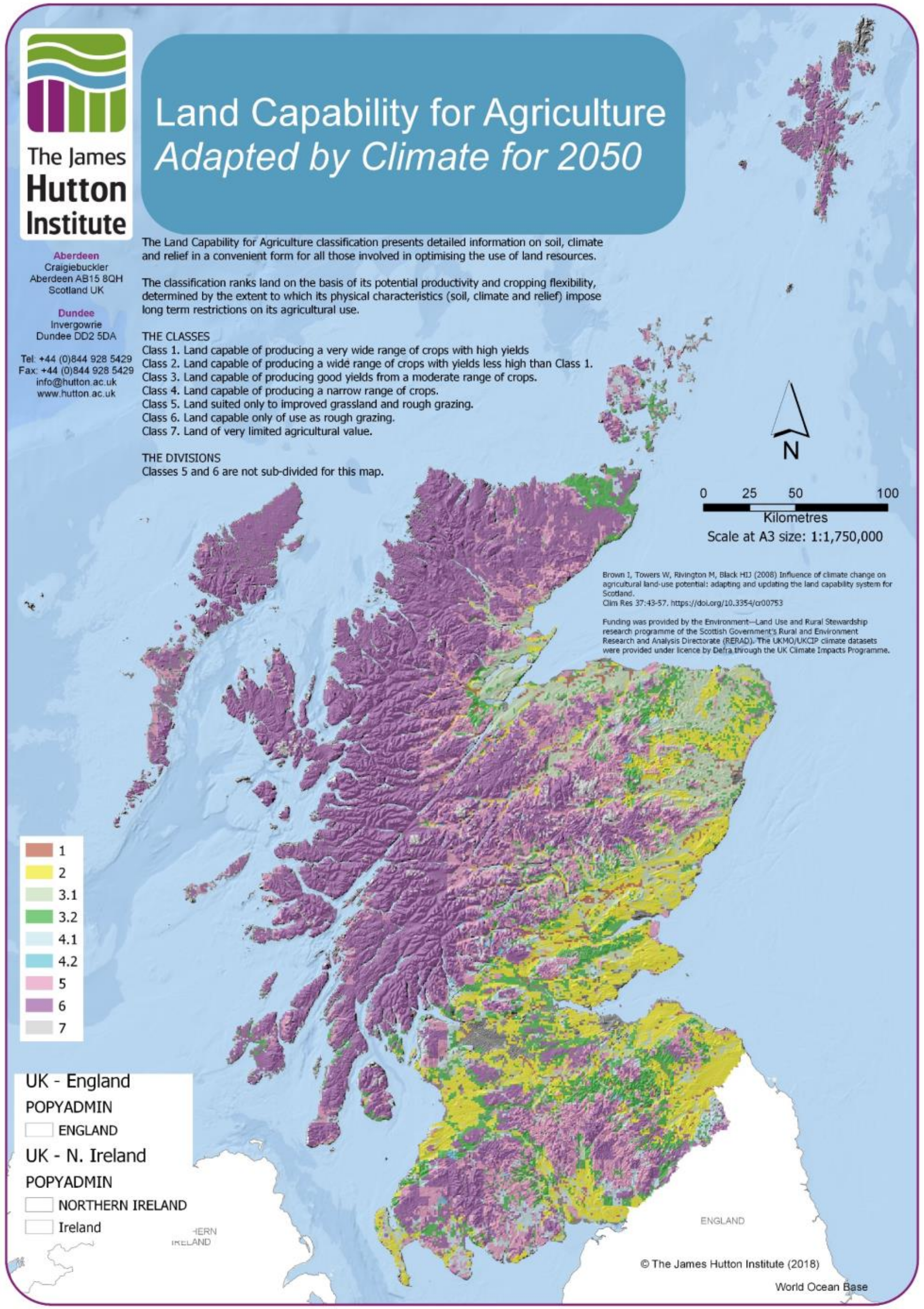
Using living labs and inter-disciplinary approaches to develop social and systems innovation in food systems using agroecology



Challenges and comparative advantage in Scotland







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Comparative Advantage is changing - Future LCA

- Increases in class 2 and 3 area based on changes in climate constraints
- Other constraints (drainage, stoniness, soil depth etc.) remain.
- Increased risk for classes 1-3 due to drier soils

Note: this version is for medium-high emissions scenario

Scotland’s climate future is more variable – take rainfall

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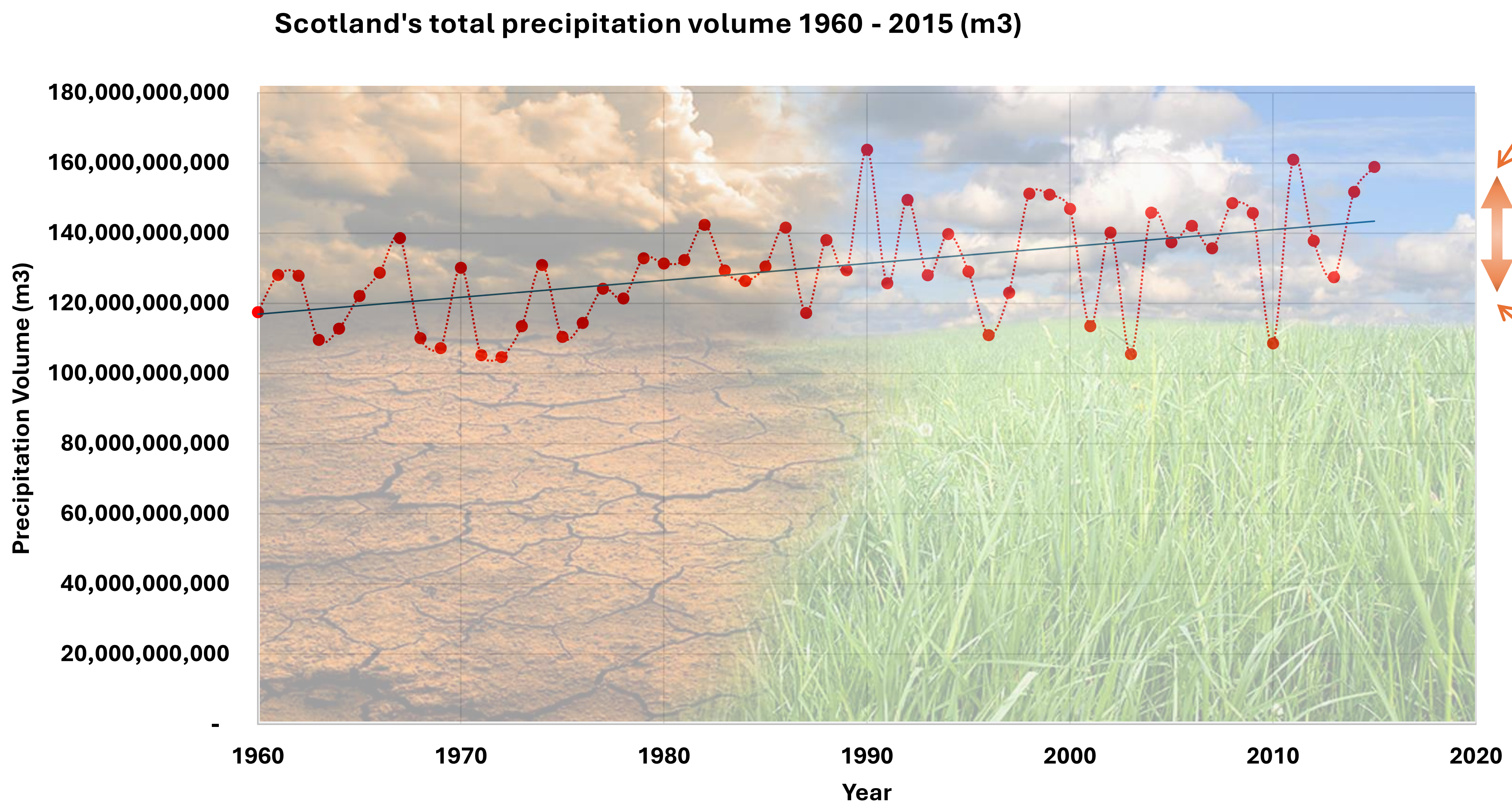
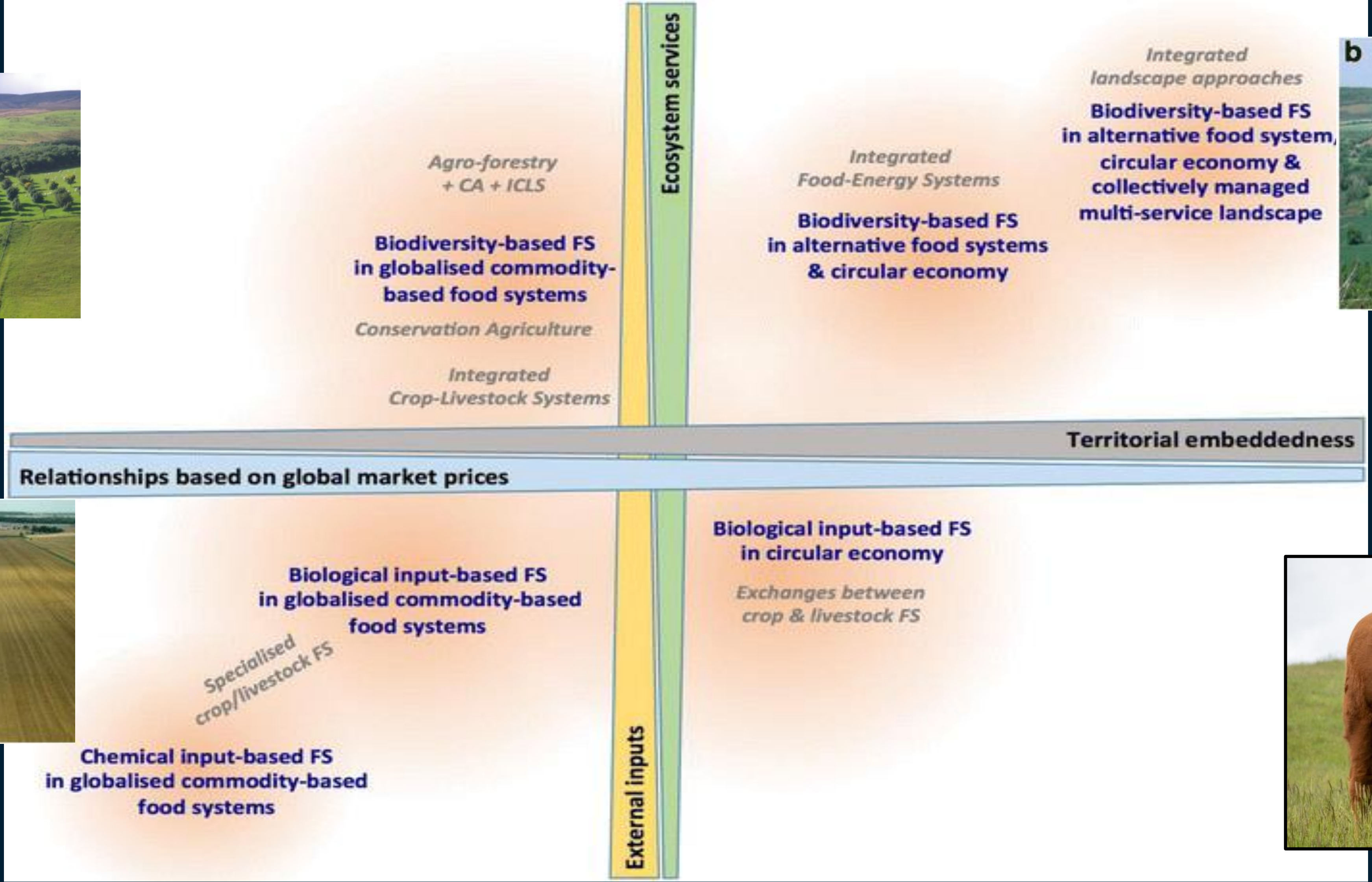


The volume of water in top 1m all our soils = 40,000,000,000 m^3 and is more than all the water in our freshwater Lochs

Mike Rivington

New farming / land systems

From: A new analytical framework of farming system and agriculture model diversities. A review Six key models of agriculture (*blue text*) according to the degree to which biotechnical functioning of farming systems (*FS*) is based on ecosystem services versus external inputs (*Y*-axis) and the degree to which their relationships with socio-economic contexts are based on global market prices versus territorial embeddedness (*X*-axis). Iconic examples are presented in *grey*. *CA* conservation agriculture, *ICLS* Integrated Crop Livestock System



Therond, O., Duru, M., Roger-Estrade, J. *et al.* A review. *Agron. Sustain. Dev.* **37,** 21 (2017). https://doi.org/10.1007/s13593-017-0429-7

Scotland’s 1st Vertical Farm at IGS Ltd’s Crop Research Centre at Invergowrie

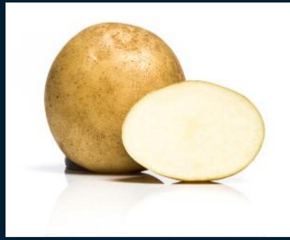
The James Hutton Institute

- Technologies converge
  - Tuneable, precision LED lighting (photonics)
  - Artificial Intelligence
  - Smart Sensors for plant growth
  - Smart energy management systems
  - Robotics
  - Plant breeding science

- Aligned with Scotland's needs and comparative advantage
  - Fresh, local, more nutritious fruit and veg
  - Using our abundant water and renewable energy
  - Can have lower GHGe than glasshouse or open field systems

> 100 years of breeding – over 200 plant varieties bred by the James Hutton Institute, its commercial subsidiaries and predecessors

The James **Hutton** Institute



100 Potato

26 Barley

2 oats

26 Brassica, Turnip & Swede

2 Kale

2025 - 1st

Scottish Blueberry – Highland Charm

27 Blackcurrant

25 Raspberry

3 Strawberry

3 Blackberry

- **Mostly bred for high input systems and yesterday's climate using conventional breeding**
- **Don't have 100 years to adapt and must accelerate breeding for new farming approaches and especially regenerative low input systems and variable climate**

Crop Innovation Centre at Invergowrie

The James Hutton Institute

- Germplasm collections for potato, barley and soft fruit
- Climate Simulator Facility: accelerating crop adaptation – temperature, drought, elevated CO_2
- Speed Breeding – total control agriculture including indoor vertical farms
- Adavanced Genomic and Molecular Profiling
- High Through-put crop phenotyping
- High performance Computing and Data Centre
- New genetic tools – Maxy-ID using dRenSEQ; Gene editing
- Field and farm scale testing

THE POTATO FEEDS AND NOURISHES

one in seven people globally and supports livelihoods for millions

1 BILLION

people eat potato –often where/when other crops scarce

3rd MOST IMPORTANT

food crop globally after rice and wheat

CROP CYCLE < 90 DAYS

complement wheat/rice

380 MILLION TONS

produced annually

10s OF MILLION OF SMALL-SCALE FARMERS AND BUSINESSES

in Africa, Asia and Latin America depend on potato for cash incomes and wellbeing

1 MEDIUM-SIZED POTATO BOILED,

provides half adult daily requirement of:

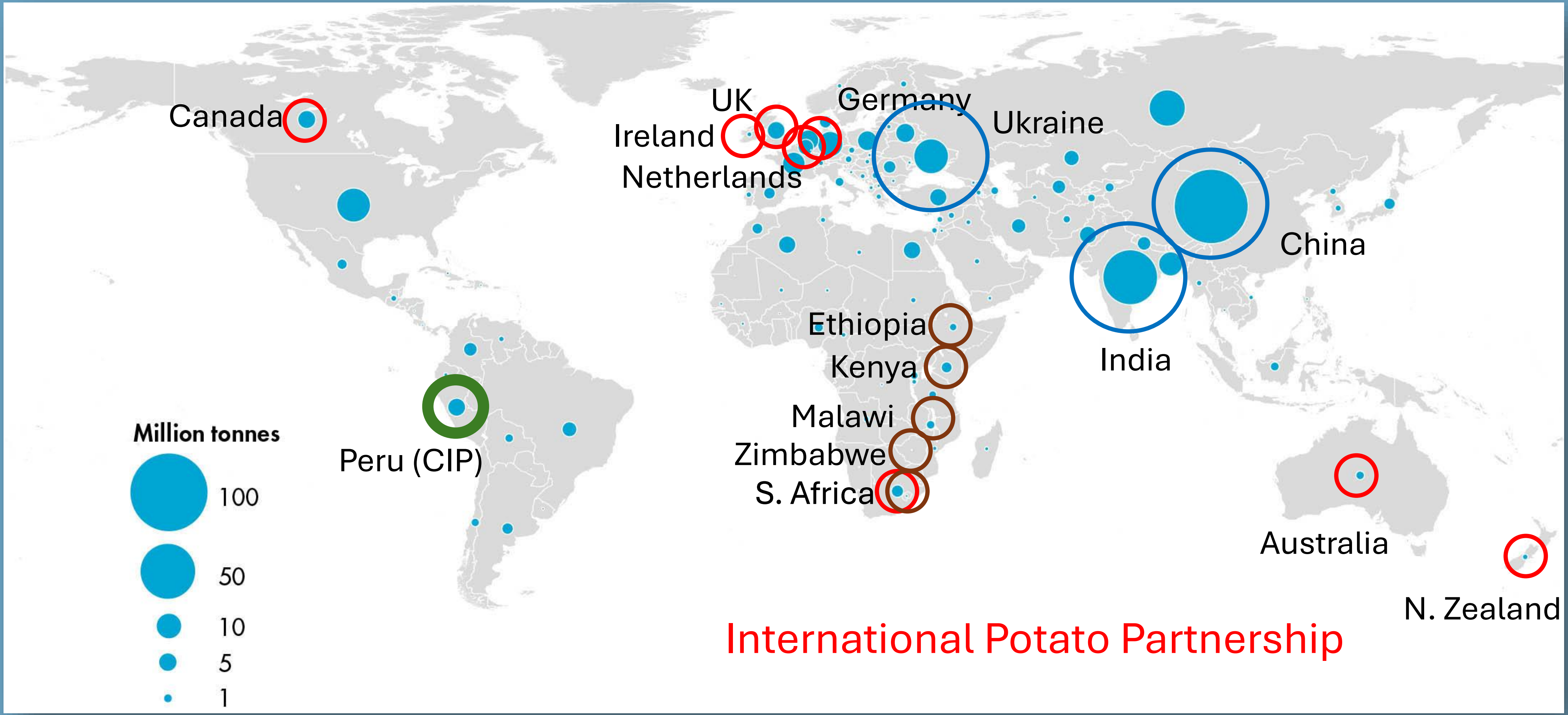
Vitamin C / Iron / Potassium

The first vegetable grown in outer space by NASA in 1995

It Is Possible To Survive Only On Potatoes

- Uniquely amongst all staple crops Potatoes contain all 26 of the essential amino acids you need to survive, including Tryptophan, found in abundance in meat
- Also has key macro (K) and micronutrients (Fe), Vitamin C and carbohydrates that are more gut friendly than many other modern varieties of staple crops

Potato - our national and international links



Commonwealth Potato Collection (CPC)

- 1500 accessions of ca. 80 wild and cultivated potato species
- Origin - South or Central America 1920/30s

Accelerated potato breeding using genomics

Amanpreet Kaur [1,2], Drummond Todd[3], Vanessa Young[3], Xinwei Chen[1], Ingo Hein[1,4]
James Hutton Institute, Dundee International Potato Center, Peru, James Hutton Limited, Dundee

- Disease-related crop losses - £50 million annually controlling late blight alone. Potato cyst nematodes further endanger the seed industry.
- Genomic tools, particularly diagnostic Resistance gene enrichment Sequencing (dRenSeq), have transformed resistance breeding.

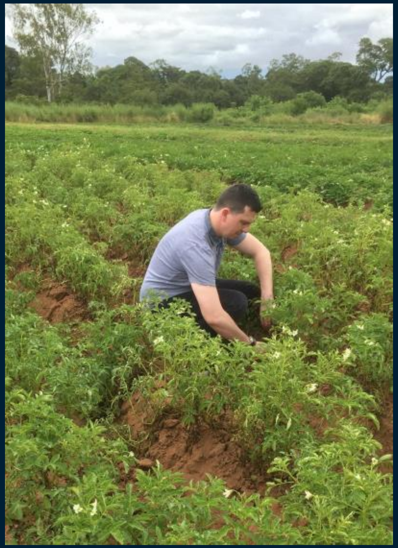


CPC diversity → Genomics/genetics → Breeding

- We generated high-resolution disease resistance gene profiles for 1043 samples including varieties, wild species and breeding clones worldwide. This resource informs parental selection, enables strategic stacking of disease resistance genes against major pests and diseases, and accelerates marker development.
- Critically, it has shortened the breeding cycle from 10 – 12 years to as little as 7 years, expediting delivery of resistant, high-performing potato varieties to growers.

Impact - Quikgro potatoes

- Potato is the 2nd largest crop in Kenya with 800,000 growers in the country with an annual production value of c£300 million.
- The potato value chain supports >2.5m people.
- Doubling yields with just ~40% of farmers would result in a 0.3% increase in Kenya's GDP
- Over to Ian .....


New potato lines for East African smallholder farmers

- **New potato varieties that combine disease resistance with traits required by growers**
  - Resistance against **PCN** – a new, major pest in the region
  - Low dormancy, quick cooking times
- **A multidisciplinary study that combined plant and social sciences expertise in UK and Kenya**
  - Develop an understanding of grower needs and potential barriers to uptake
  - Genetic characterisation of PCN present in the region
  - Crop breeding and field trials
- **Two varieties – “Glen” and “Malaika” – released in Kenya**
  - Scale up of seed tuber production in progress
    - Commercial – Kisima Seeds
    - Smallholders - Farmer hubs



The James Hutton Institute

John Jones – “This was surprisingly emotional to see yesterday. First generation of seed tubers of Malaika and Glen being harvested at Kisima Farm.”

Delivery partnerships, particularly private sector, are key to achieving impact

SAF Sustainable Agriculture Foundation

CIP INTERNATIONAL POTATO CENTER

Seeds2B AFRICA

KISIMA

Heat tolerant and early maturing potato varieties for Malawi

- **Collaborative research between JHI, CIP and DARS**
  - identified potato clones incorporated traits for heat tolerance, early maturity and disease resistance.

- **Environmental and household benefits**
  - Shorter cooking time saves firewood—Malawi's primary household cooking fuel.
    - helping preserve forests and reduce household (women's) labour.

- **Five varieties – "Tinyadile, Chikoka, Khutula, Chitute, & Phindu" - released**
  - Yielding between 28-36 t/ha (nat. av. 17 t/ha)

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CIP INTERNATIONAL POTATO CENTER
MALAWI GOVERNMENT
University of St Andrews
Scottish Government Riaghaltas na h-Alba gov.scot
BBSRC bioscience for the future
Ireland

Comparative advantage and partnership models

- Comparative strengths of JHI (Scottish institutions) and CIP (CGIAR Centers) and their partners provide capacity and ability to address pressing current and future issues in global food security
  - World-class science base in Scotland- potatoes, barley, livestock etc.
  - CGIAR with 2500 scientists working in crop genetic innovation on 21 crops in 130 countries with extensive national partner networks
- Effective partnership models provide clarity on roles and funding mechanisms
  - JHI CIP MOU recently renewed
    - Joint appointments
  - New UK CGIAR virtual Centre provides mechanisms and funding to link UK science base to CGIAR Centres
    - Secondments

UK-CGIAR CENTRE

Collaboration in Science and Innovation

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UK International Development Partnership | Progress | Prosperity
UKRI Biotechnology and Biological Sciences Research Council
CABI
CGIAR

Conclusion

- Play to comparative institutional strengths.
- Huge potential to address pressing issues in global food security and Scottish Institutions well placed to play a key role in a number of key commodities.
- Benefits work both ways and investments and collaboration in overseas development also generate significant return back to UK agriculture - Scottish farmers see and face many of same opportunities and issues as those in the Global South.

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Contributing authors

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John Jones, Ingo Hein, Aman Kaur, Alison Lees, Ian Toth, Paul Shaw, Micha Bayer

- Danny Coyne, IITA


Aman


Ingo


Lesley


John


Trinity


Danny


Pete


Ian

The James Hutton Institute | University of Dundee | IITA | University of St Andrews | icipe | CIP International Potato Center | syngenta foundation for sustainable agriculture | RESAS Rural & Environmental Science and Analytical Services

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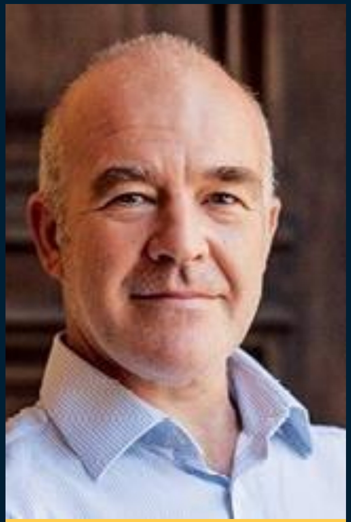
Edwini Kessie

WTO



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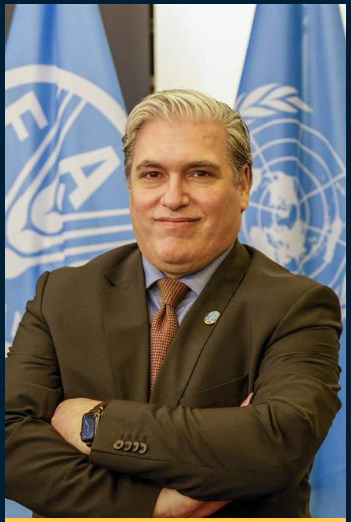

Raschad Al-Khafaji

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Hillary Curnow

New Zealand High Commission

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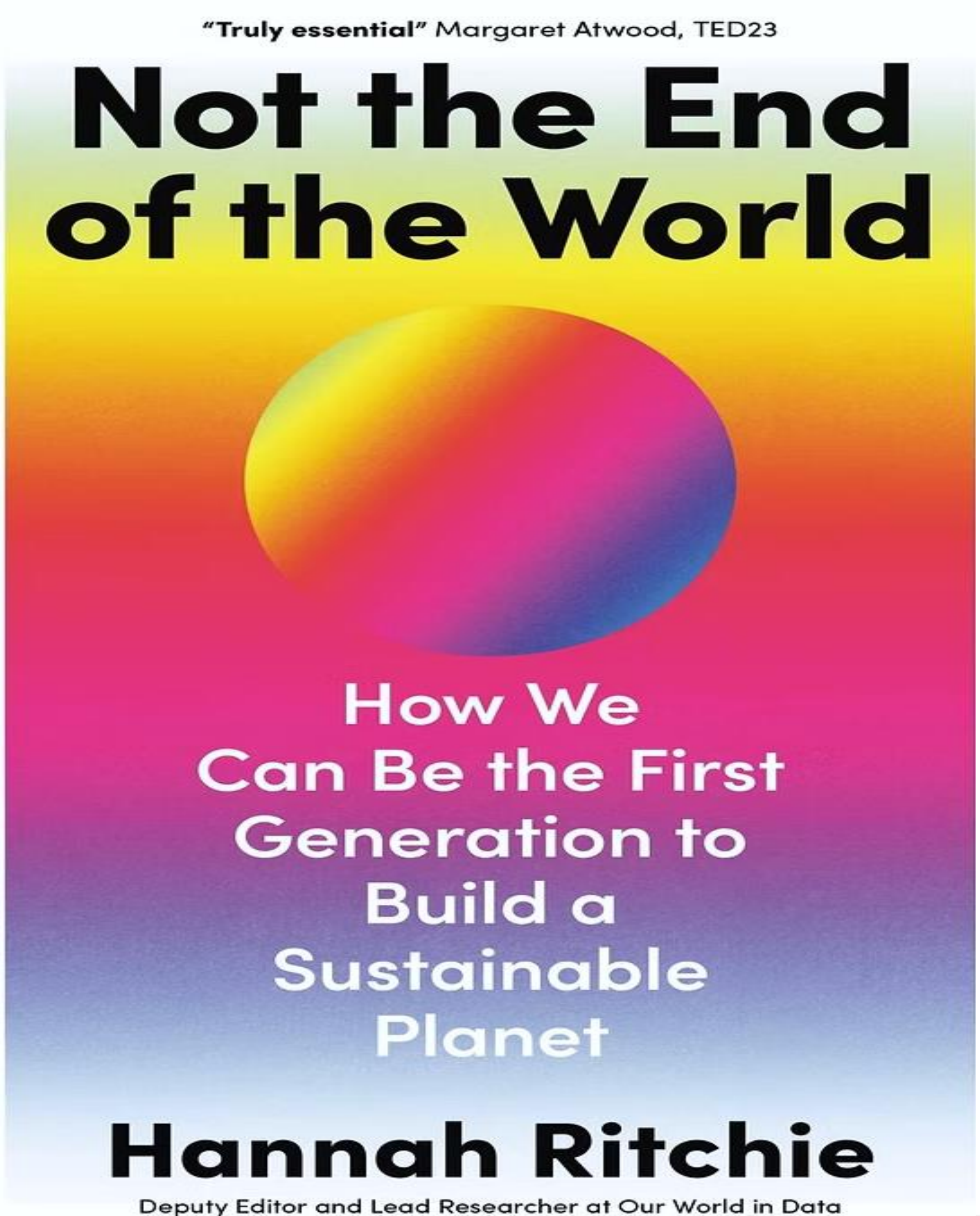
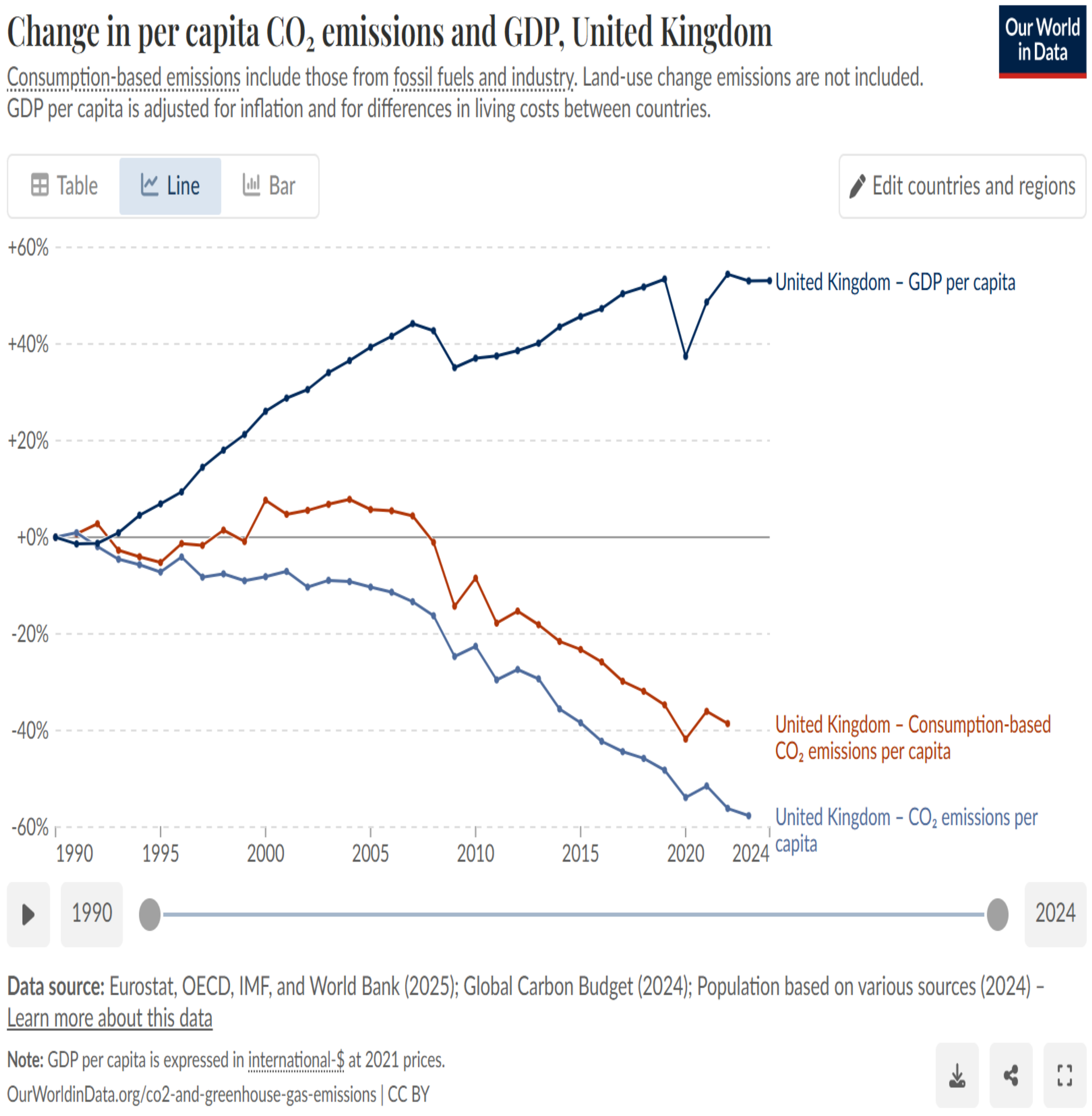
Genetics, Data and Innovation: Breeding for National and Global Food Security

Professor Wayne Powell, SRUC
Dr Matthew Cleveland, Genus plc


"Truly essential" Margaret Atwood, TED23
Not the End of the World
How We Can Be the First Generation to Build a Sustainable Planet
Hannah Ritchie
Deputy Editor and Lead Researcher at Our World in Data


Change in per capita CO_2 emissions and GDP, United Kingdom
Consumption-based emissions include those from fossil fuels and industry. Land-use change emissions are not included. GDP per capita is adjusted for inflation and for differences in living costs between countries.
Our World in Data
Table
Line
Bar
Edit countries and regions
+60%
+40%
+20%
+0%
-20%
-40%
-60%
1990
1995
2000
2005
2010
2015
2020
2024
United Kingdom – GDP per capita
United Kingdom – Consumption-based CO_2 emissions per capita
United Kingdom – CO_2 emissions per capita
1990
2024
Data source: Eurostat, OECD, IMF, and World Bank (2025); Global Carbon Budget (2024); Population based on various sources (2024) – Learn more about this data
Note: GDP per capita is expressed in international-$ at 2021 prices.
OurWorldinData.org/co2-and-greenhouse-gas-emissions | CC BY

Decoupling selection from phenotyping

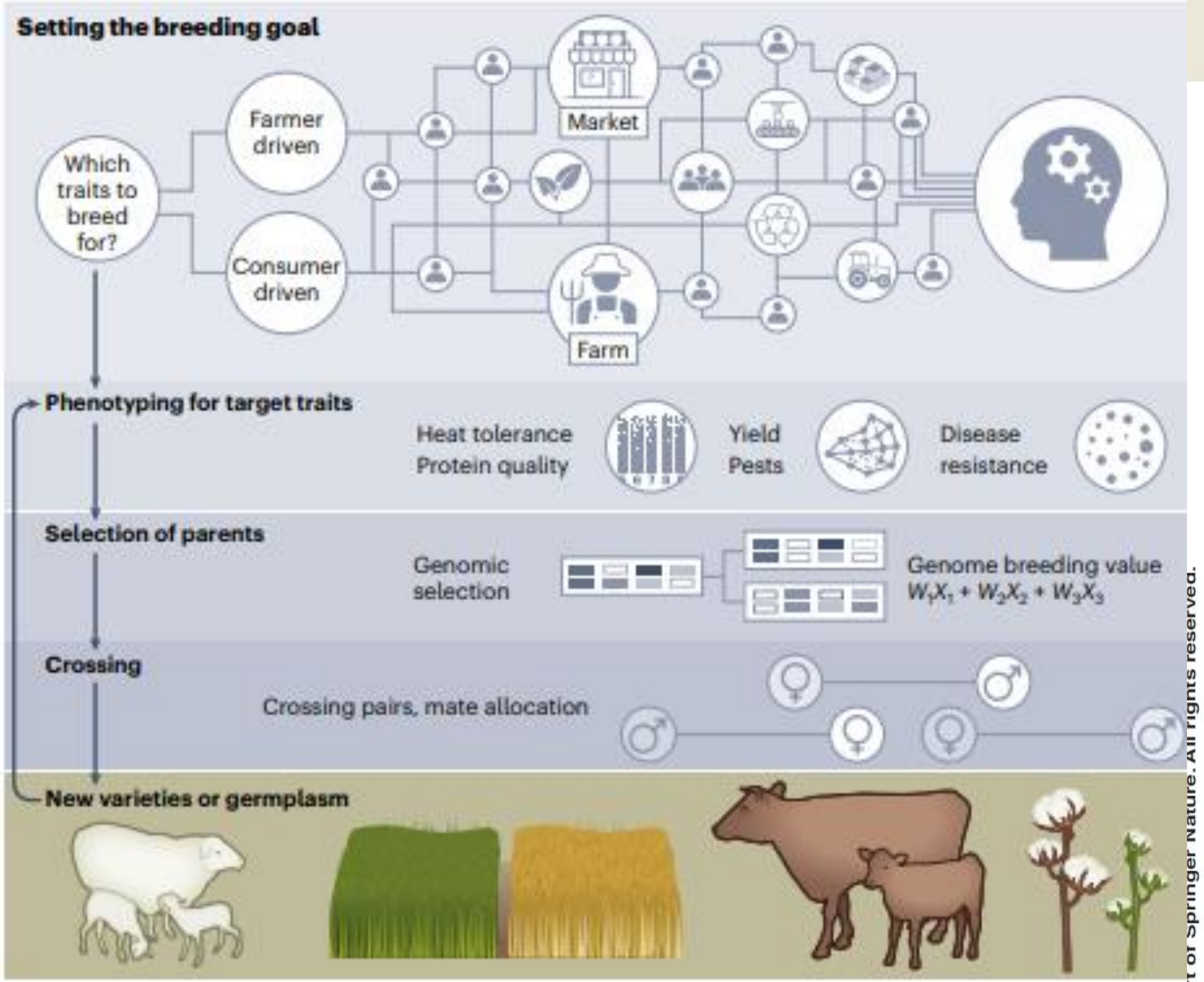


Fig. 1 | Tasks for designing breeding programs for livestock and crops. For a breeding cycle, these tasks are setting the breeding goal (including with the 1,000 minds approach[3]), phenotyping of breeding goal traits (for example, with drones), selection of parents, crossing of parents, and development of new germplasm. New germplasm may then enter a new cycle of breeding.

PERSPECTIVE

nature genetics

Genomic prediction unifies animal and plant breeding programs to form platforms for biological discovery

John M Hickey[1], Tinashe Chiurugwi[2], Ian Mackay[2], Wayne Powell[3] & Implementing Genomic Selection in CGIAR Breeding Programs Workshop Participants[4]

The rate of annual yield increases for major staple crops must more than double relative to current levels in order to feed a predicted global population of 9 billion by 2050. Controlled hybridization and selective breeding have been used for centuries to adapt plant and animal species for human use. However, achieving higher, sustainable rates of improvement in yields in various species will require renewed genetic interventions and dramatic improvement of agricultural practices. Genomic prediction of breeding values has the potential to improve selection, reduce costs and provide a platform that unifies breeding approaches, biological discovery, and tools and methods. Here we compare and contrast some animal and plant breeding approaches to make a case for bringing the two together through the application of genomic selection. We propose a strategy for the use of genomic selection as a unifying approach to deliver innovative 'step changes' in the rate of genetic gain at scale.

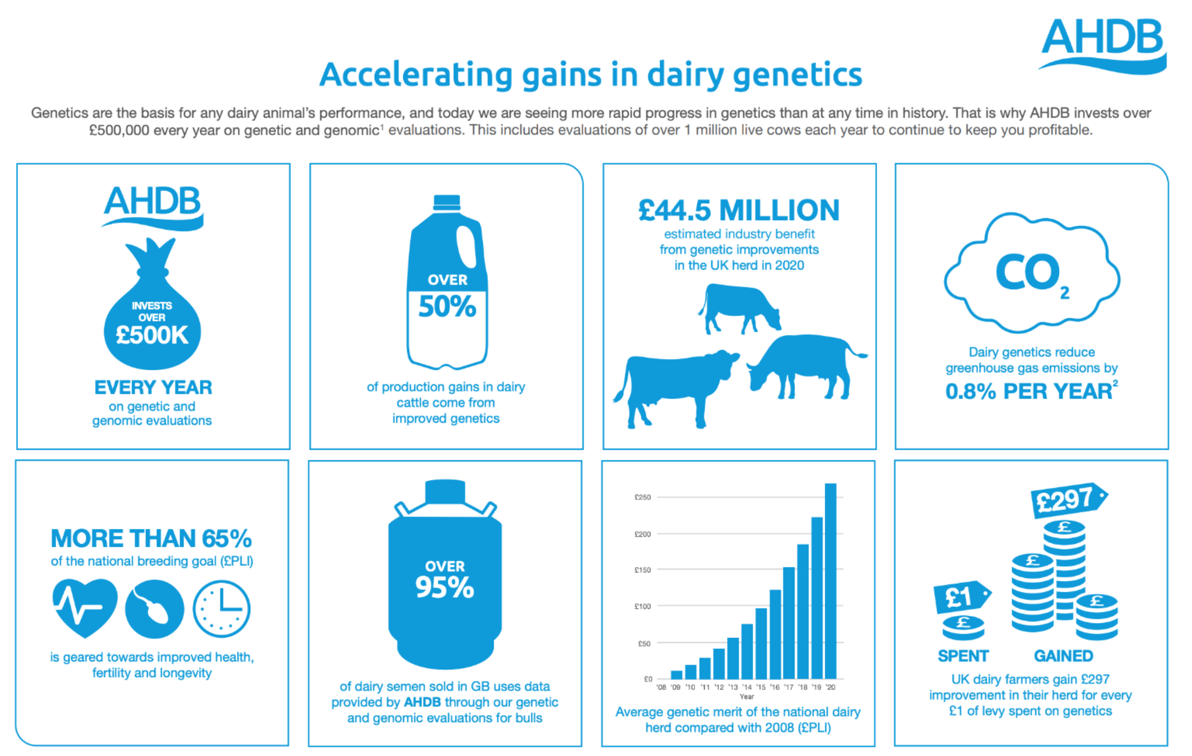
for the past century. Access at unprecedented levels to large-scale sequence and phenotypic information will bring opportunities to unify breeding methods, tools and technologies across several plant and animal species, which in turn will catalyze the modernization of breeding programs. Furthermore, we postulate that the adoption of these new technologies and approaches at scale will enable breeding programs to be platforms for both the delivery of new products and biological discovery based on genome-wide association studies (GWAS) with field validation of new alleles.

A brief history of plant and animal breeding

Breeding of livestock and crops is as old as agriculture itself. At the heart of all breeding remain such traditional pursuits as designing and analyzing performance trials to rank selection candidates in order of merit, with the aim of maximizing selection gain per unit of resources expended[5]. The history and development of scientific animal and plant breeding can be traced back to the contributions of many individuals, but there are a few outstanding additions—at least from our current

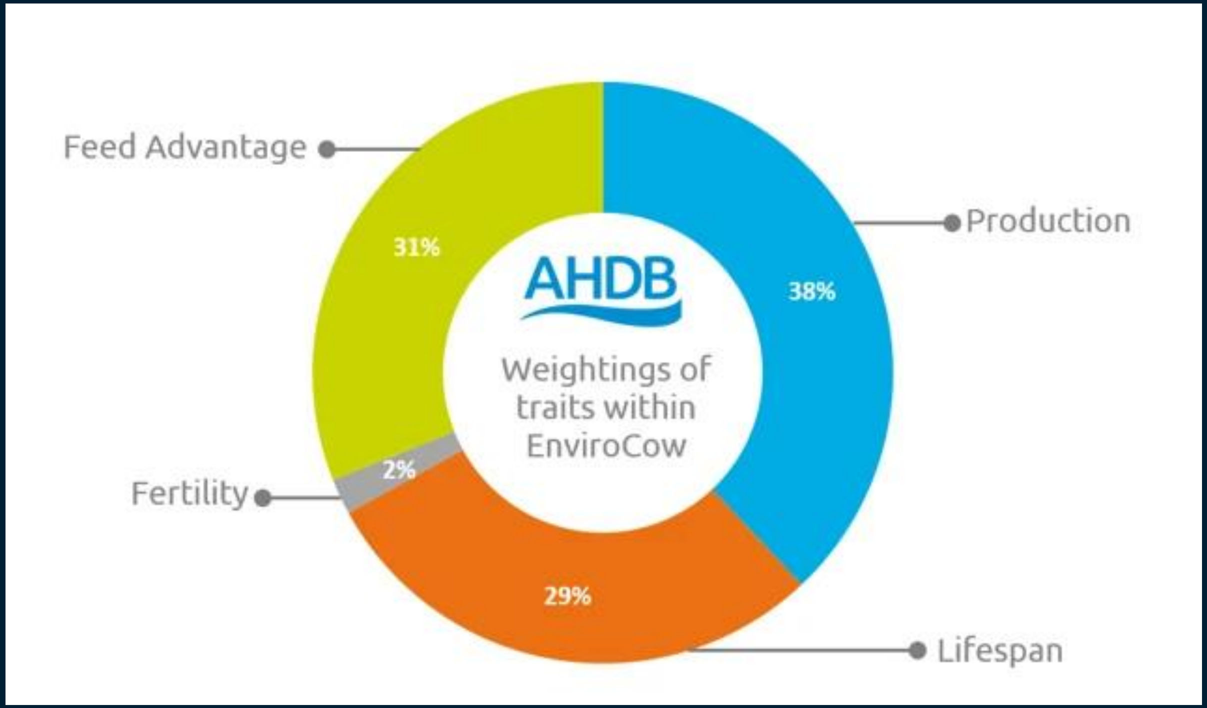
EGENES: Data-Driven Genomic Prediction

- EGENES delivers UK national genetic evaluations
- Integrates >50 million animal records across breeds and traits
- Over 112,000 females genomically tested in 2024 — up 19 % on 2023
- Each £1 invested in genetic evaluations delivers ~£297 on-farm value
- Biology from Langhill cows feeds into genomic predictions



EnviroCow: Linking Genetics, Efficiency and Sustainability

- EnviroCow Index links genetics, feed efficiency and methane traits across ~475,000 cows
- Each point delivers ↓10 % methane, ↓10 % feed intake, ↑33 % lifetime solids yield
- Cutting UK dairy emissions by 1% each year through genetic gains
- Foundation for future links with the rumen microbiome and climate-smart breeding



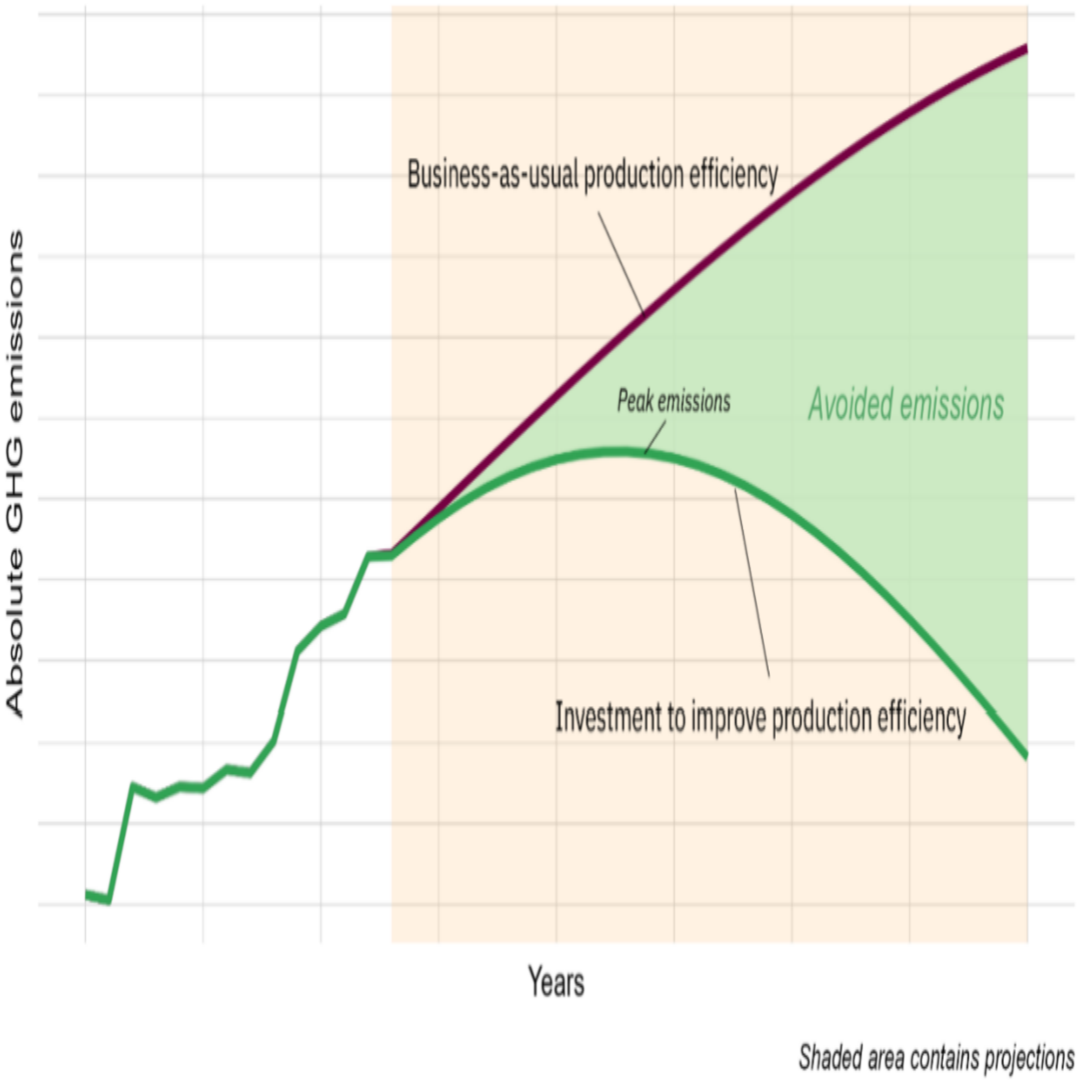
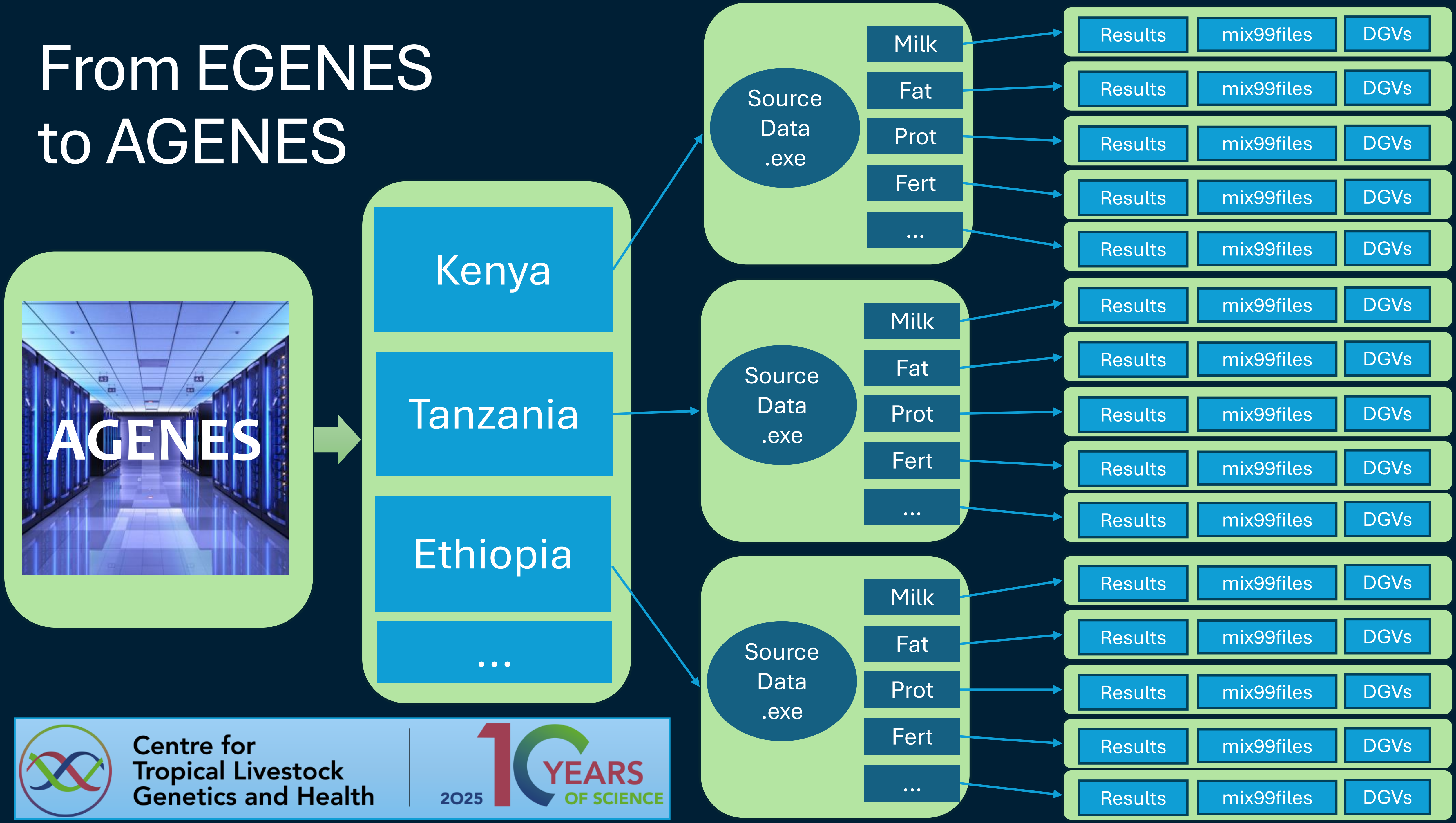


Figure 2. To understand the potential for avoided emissions, or bending the emissions curve, we must consider two alternative scenarios for the future of livestock production in LMICs. One where production efficiency does not improve significantly and one where investment leads to improvement. The difference in absolute emissions between these two scenarios is the potential for avoided emissions (green area).

From EGENES to AGENES



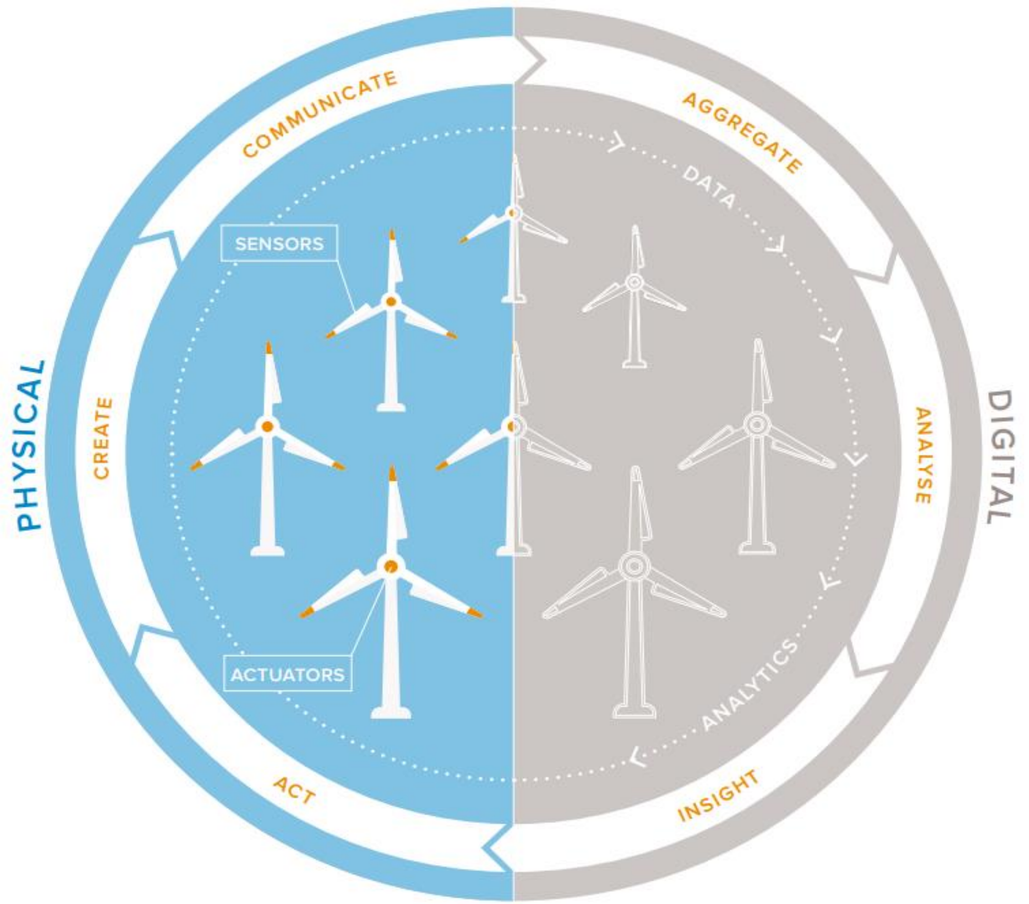
Centre for Tropical Livestock Genetics and Health

2025 10 YEARS OF SCIENCE

A novel data science-driven approach is needed to develop a high-quality common evidence base to underpin land use decision

FIGURE 2

A digital twin is a virtual representation of a physical asset which can be used to understand, predict and optimise the performance of this asset. Simulations can be run before an asset is built or during its use, with then the possibility to feedback real-time data. This feedback loop enables a control loop, with the possibility to adjust the real-world set up based on insights from the simulation. Digital twins can also be used to carry out stress tests, and to explore the impact of new policies or interventions.

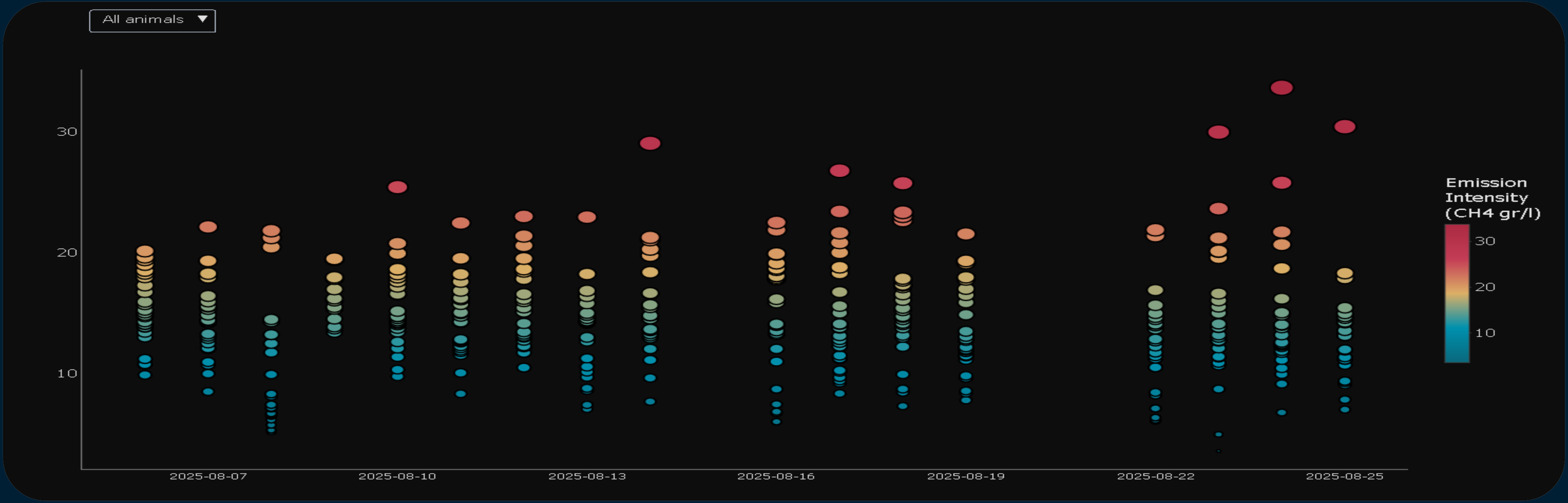


Dairy Digital Twin-Farm Twin

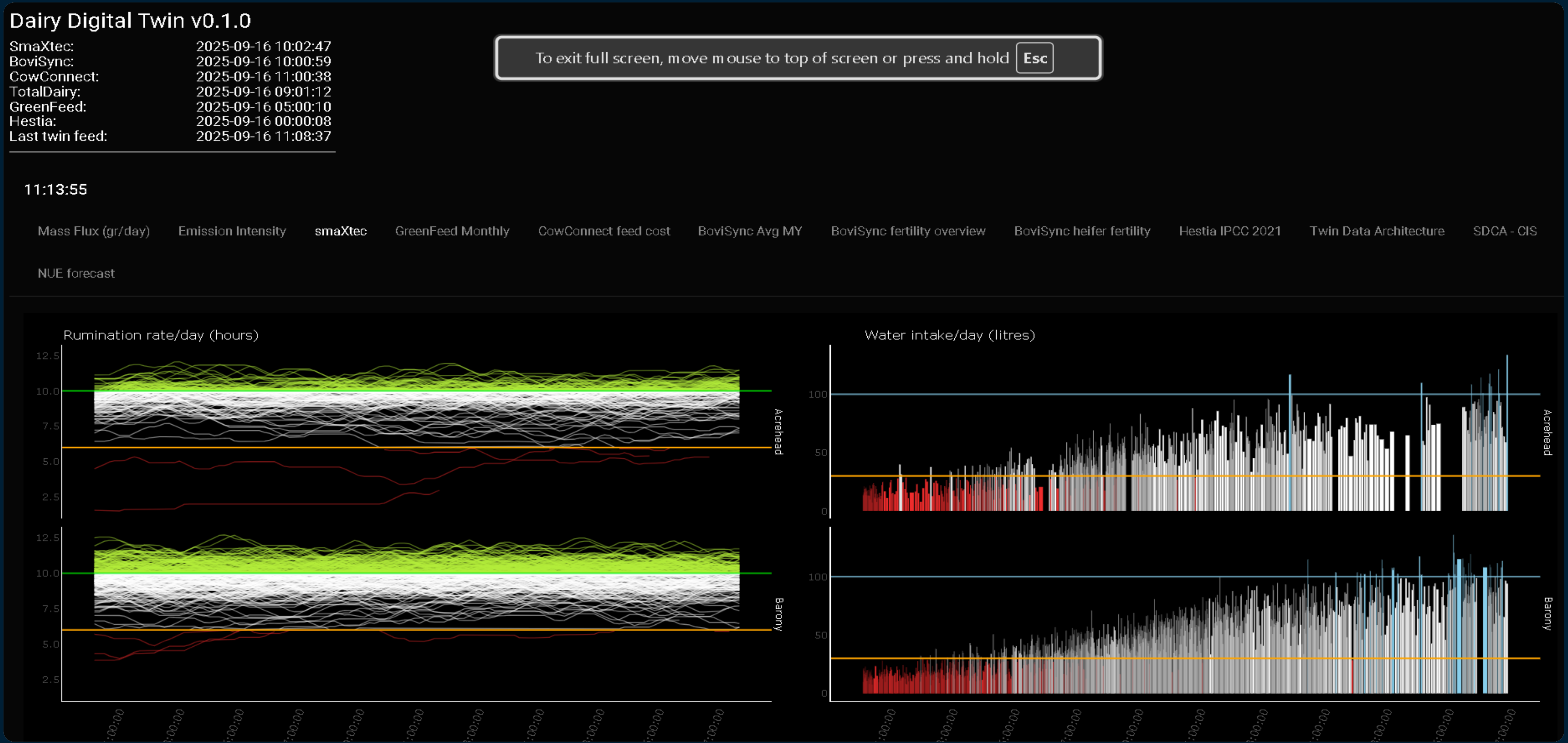
- More than 44,000 API calls per year (constantly growing)
- Total 6,199,680 data operations (twin feed every 3 minutes)
- Released free and open source: https://dairydigitaltwin.sruc.ac.uk
- Building a developer community, including working directly with technology providers
- Combining data from several systems to create a single point of truth for the farm

Digital Twins: Simulating the Future Farm

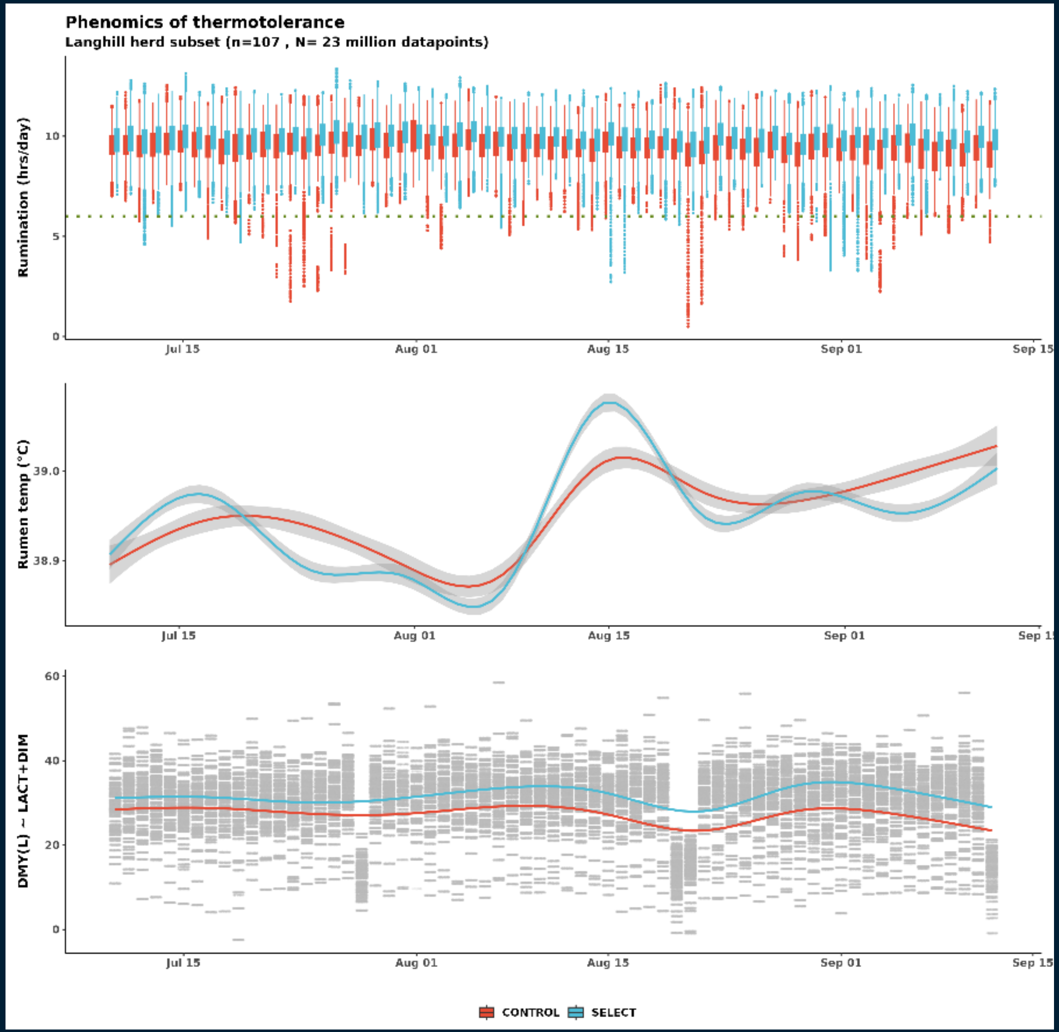
- Digital twins link feed, health, emission and genetic data in one model
- Virtual testing of “what if” scenarios before real-world implementation
- Reduces cost, risk and carbon intensity in farm decision-making

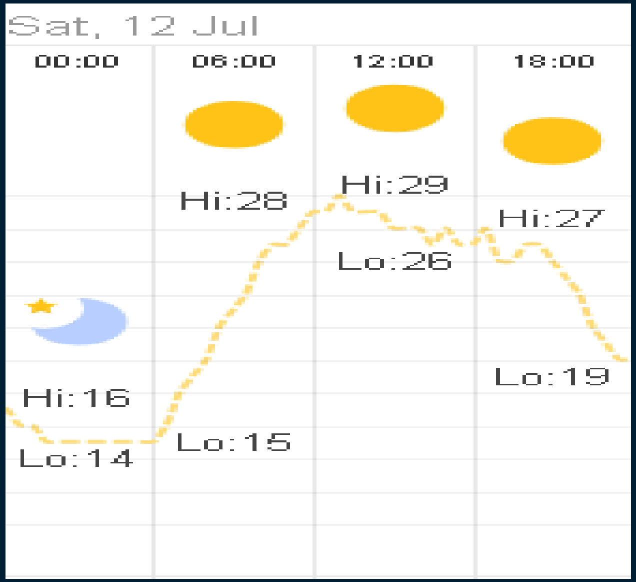


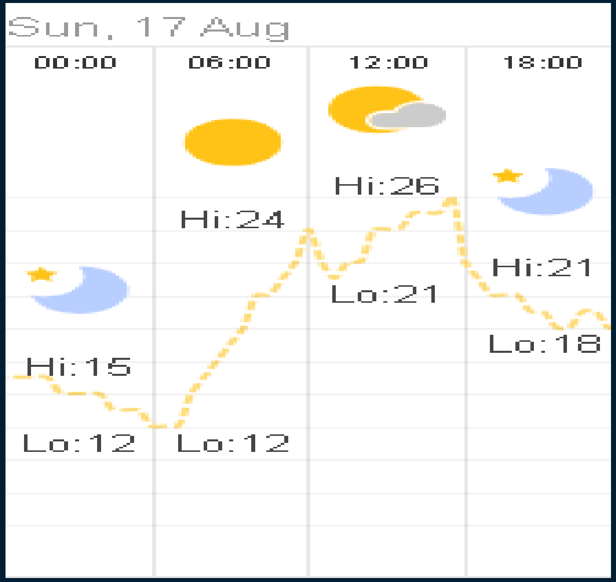
Real Time-digital phenotyping drive future livestock innovation & breeding



Digital Phenomics of Thermo-Tolerance

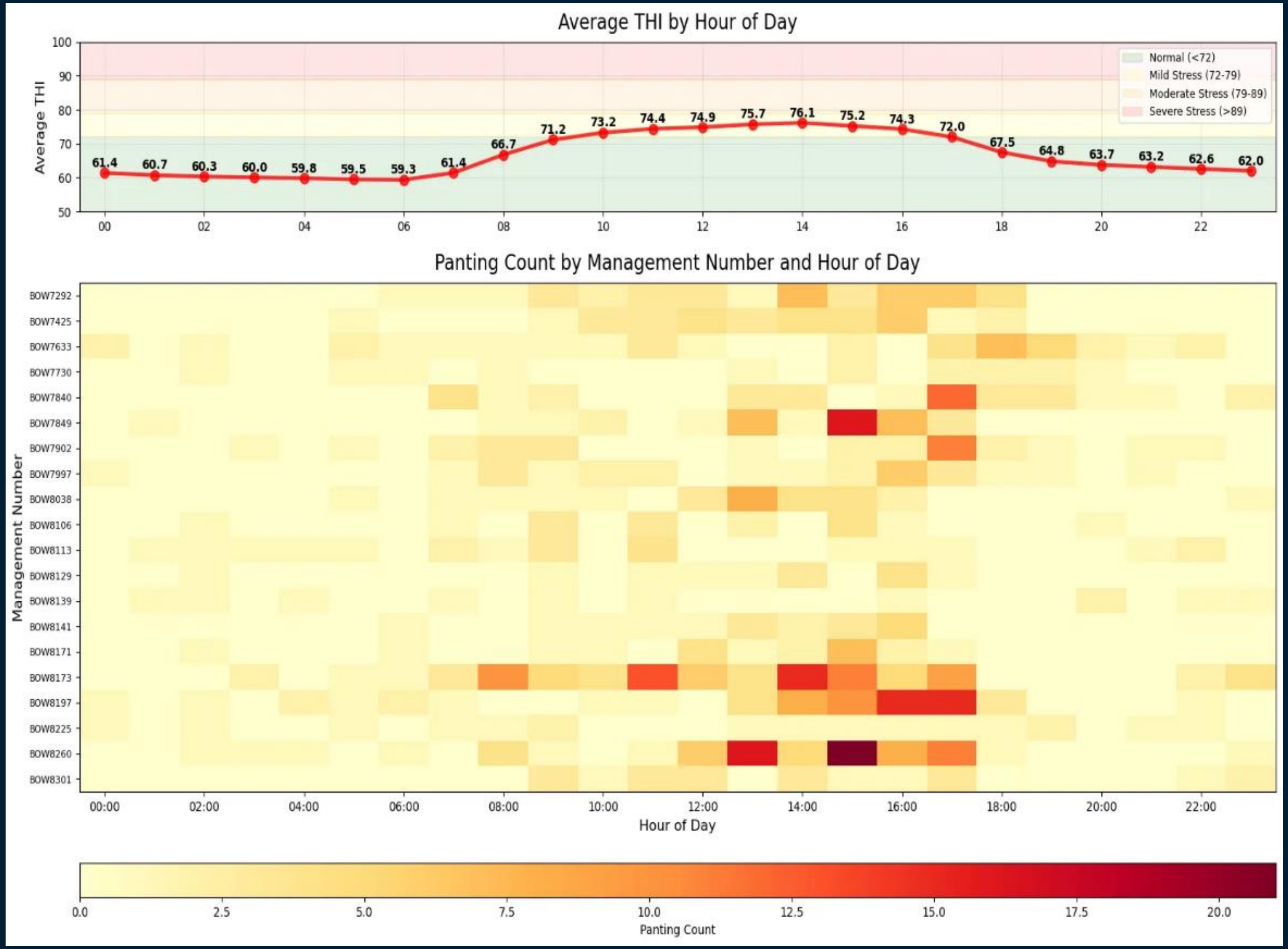






- Genetic covariance diff
- Compounding effect of HT
- Response patterns in rumination time
- Resilience vs Robustness phenotype

Kapiti Digital Twin for Thermo-tolerance & Behavioural Traits



Innovation in Breeding

SRUC

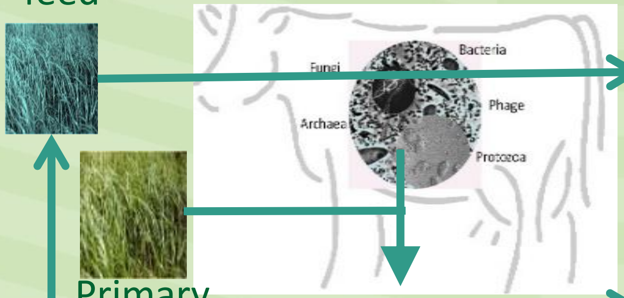
Conventional breeding practice

Trials
Phenotype
Omics
Genotype

$y = Xb + Zu$ Genomic prediction

Trait modelling
Breeding decision

Improved feed



Primary feeds

Low emissions

Improved productivity

Integrated Trait selection

Breeding with digital twinning

$y = Xb + Zu$

Cloud computing

Real-time simulation

Develop digital twin & AI framework for selective breeding with microbes, plants & animals

New Training Populations & Digital Phenotypes that enables prediction for both productivity, environmental, utilisation, health and behavioural traits

The Fourth Industrial Revolution

- The story of growth is a story with two 'is' – ideas and institutions.
- 'In future, institutional innovation will be every bit as important as technological innovation if that gift of growth is to keep on giving'.
- Andy Haldane Ideas and Institutions – A Growth Story 2018

Scaling innovation to create a more sustainable food supply

Genetic innovation is the most important tool for permanent reduction of environmental impact and more sustainable livestock production

Scaling genetic innovation to create more sustainable commercial systems

Sustainability requires profitability

Incentivise the right behaviour through supply chain signals

Implement with enabling technologies at farm level

Overcome barriers to disseminate improved genetic

Genus ABS

Quantifying the genetic impact on beef x dairy environmental footprint

- Two beef genetic lines selected for beef x dairy supply chain performance in US and UK
- First LCA for beef x dairy production; framework to account for genetic merit
- Climate change impact reduction potential of **5-9%** due to genetic improvement

UKRI Innovate UK

Genus ABS

Targeted genetic improvement has the potential to reduce **beef x dairy** climate impact by nearly 1 million tonnes CO_2e over five years in the UK, while continuing to improve productivity and profitability

Genetic innovation: Microbiome-driven breeding

- Rumen: a unique symbiotic system where microbes turn feed into energy and protein; methane is a by product
- Fundamental 2016 work demonstrated that rumen microbes are influenced by host genetics; can select for composition of the microbiome

PLOS | GENETICS

Award-winning paper

RESEARCH ARTICLE

Bovine Host Genetic Variation Influences Rumen Microbial Methane Production with Best Selection Criterion for Low Methane Emitting and Efficiently Feed Converting Hosts Based on Metagenomic Gene Abundance

Rainer Roehe[1]*, Richard J. Dewhurst[1], Carol-Anne Duthie[1], John A. Rooke[1], Nest McKain[2], Dave W. Ross[1], Jimmy J. Hyslop[1], Anthony Waterhouse[1], Tom C. Freeman[3], Mick Watson[4]☯, R. John Wallace[2]☯

CrossMark
click for updates

Prof. Rainer Roehe

SRUC

Innovate UK

Genus ABS

- Genus ABS beef breeding programs focused on delivering more productivity and profitability to beef supply chains

- Rumen microbial genes:
  - Improve feed efficiency
  - Reduce methane
  - Improve animal health

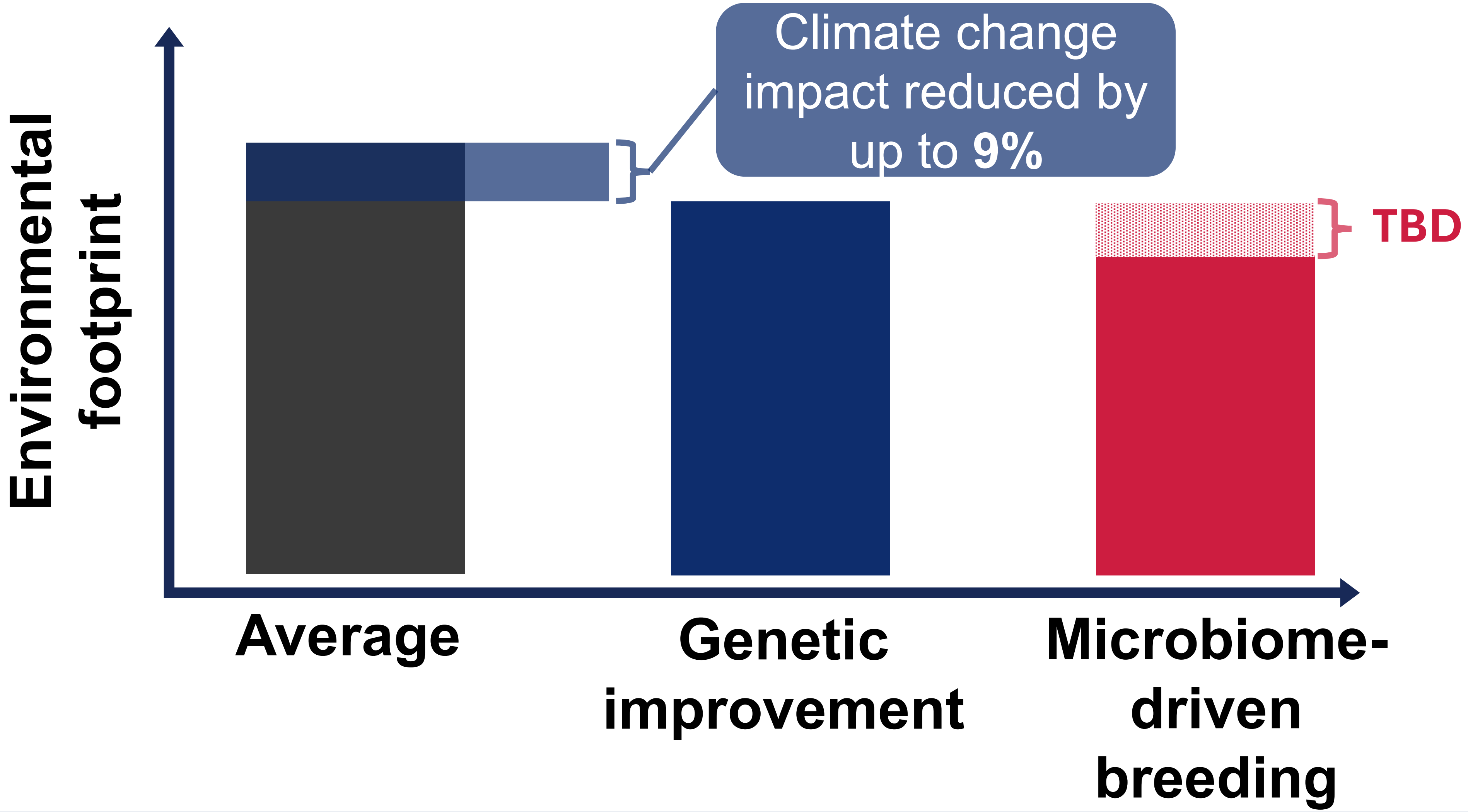
- Feed efficiency can be improved and methane production reduced simultaneously

- Trials in progress to validation microbiome-driven breeding predictions

Integration of microbiome-driven breeding into the Genus commercial breeding program

Prof. Rainer Roehe

Accelerating environmental impact reduction in commercial beef systems – in the UK and globally



Lai et al., 2025

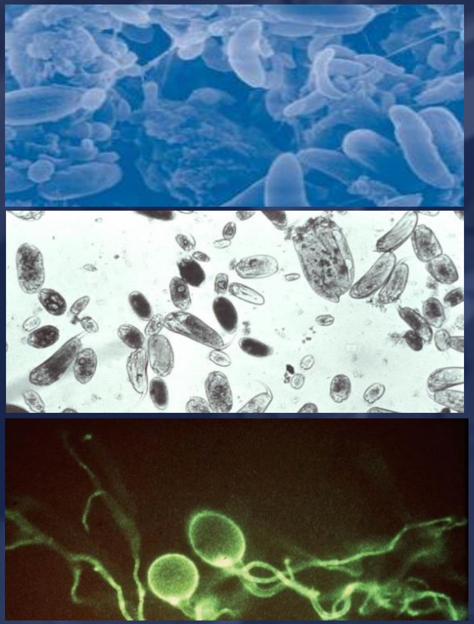
Robust phenotypes and new breeding approaches are key to scaling production of more sustainable products

Diet composition

Feed & water intake

Enteric emissions

Whole-animal emissions



Rumen composition

A more sustainable food supply, around the world, starts with genetics.

Genus ABS

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Gateway

Livestock Disease Innovation for Resilient Food Systems in Sub-Saharan Africa

Tom McNeilly, Director - Moredun Research Institute
Lena Halos, Senior Programme Officer - livestock health - Gates Foundation,

Development of a commercial *Haemonchus contortus* vaccine

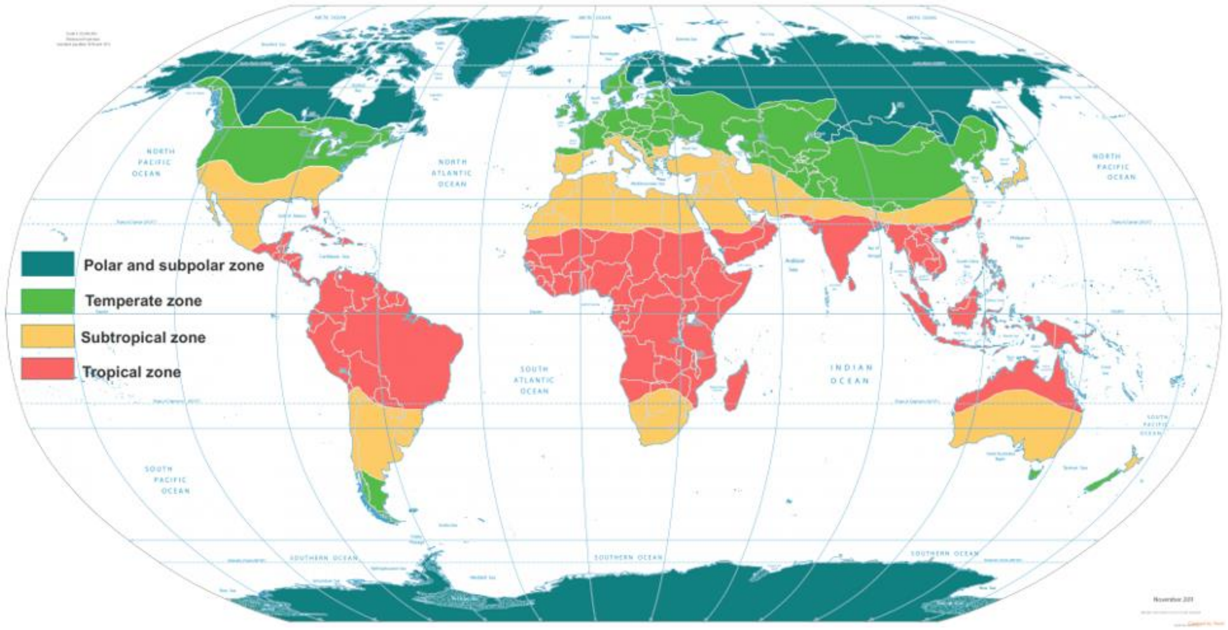
Haemonchus contortus – an economically important parasite of small ruminants

Moredun

Clinical signs

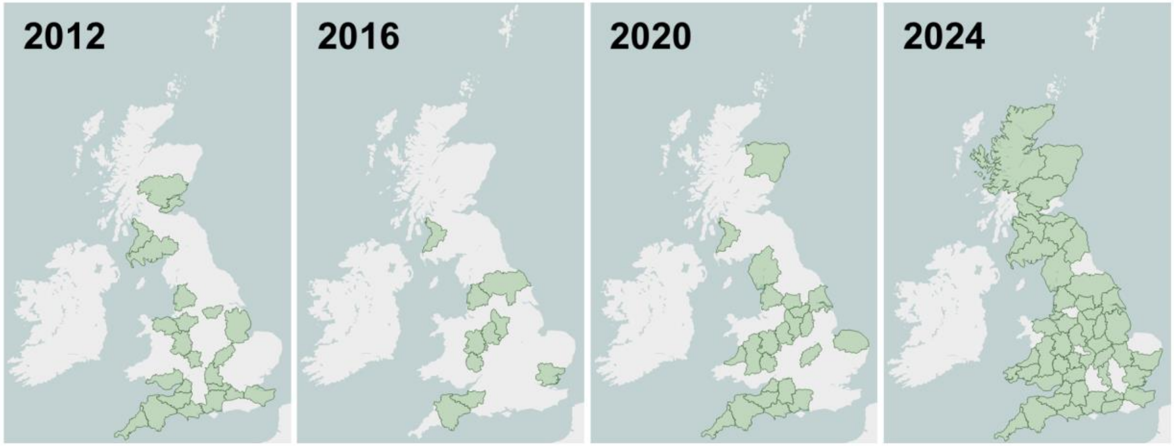
- Primarily affects sheep and goats
- Sudden death
- No evidence of poor body condition or scour in acute or sub-acute infections
- Anaemia due to blood sucking habit of the worms (0.05mL / day)
- Highly fecund - ~7000 eggs per female per day
- Bottle jaw due to hypoproteinemia
- Failure to thrive, weight loss, lethargy and weakness
- As few as 500 worms can cause disease

Haemonchus contortus widely distributed throughout tropics and subtropics…



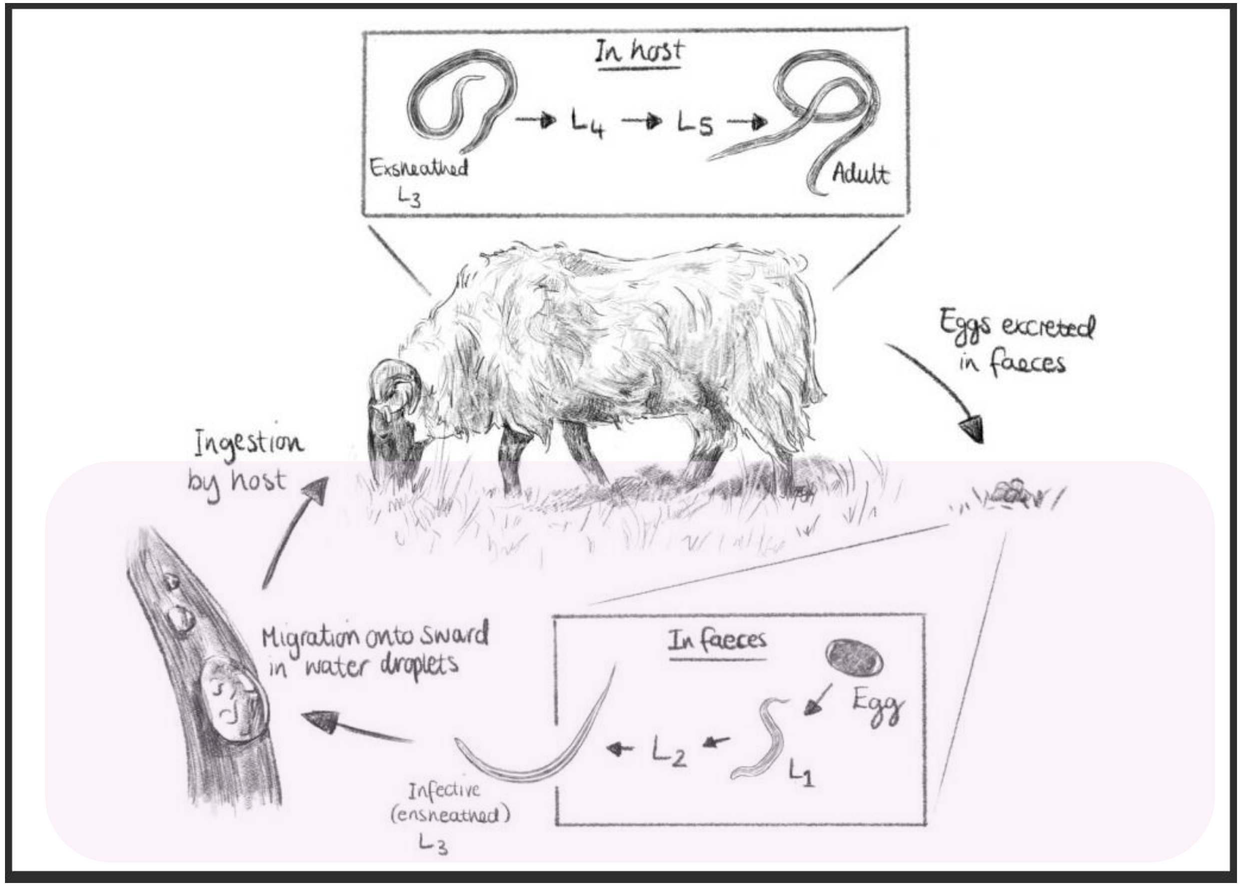
https://content.meteoblue.com/en/meteoscool/general-climate-zones

…but also increasing in temperate zones



Haemonchus contortus sensitive to climate – warmer wetter conditions favour off-host stages

Moredun



Control:

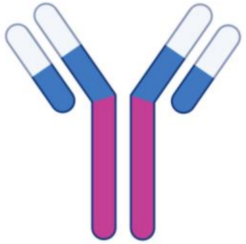
- Management
- Anthelmintics
  - *Widespread resistance*
- Vaccines

Barbervax® – a highly protective vaccine based on native worm gut membrane extract

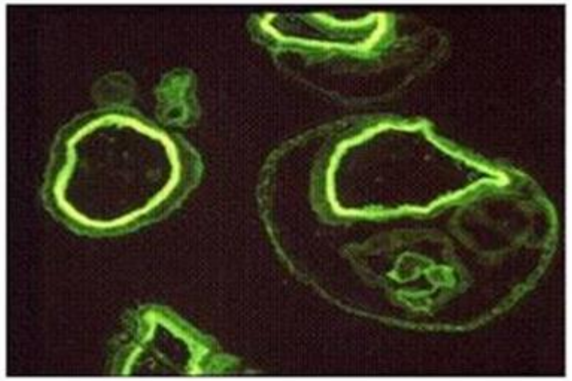
Moredun

Adult worm
gut extracts

Immunise with gut
membrane extracts



Generation of worm
gut- specific
antibodies



Antibodies bind to worm gut and
starve/kill the parasite

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MEAT & LIVESTOCK AUSTRALIA

Barbervax® – a vaccine based on native worm gut membrane extract

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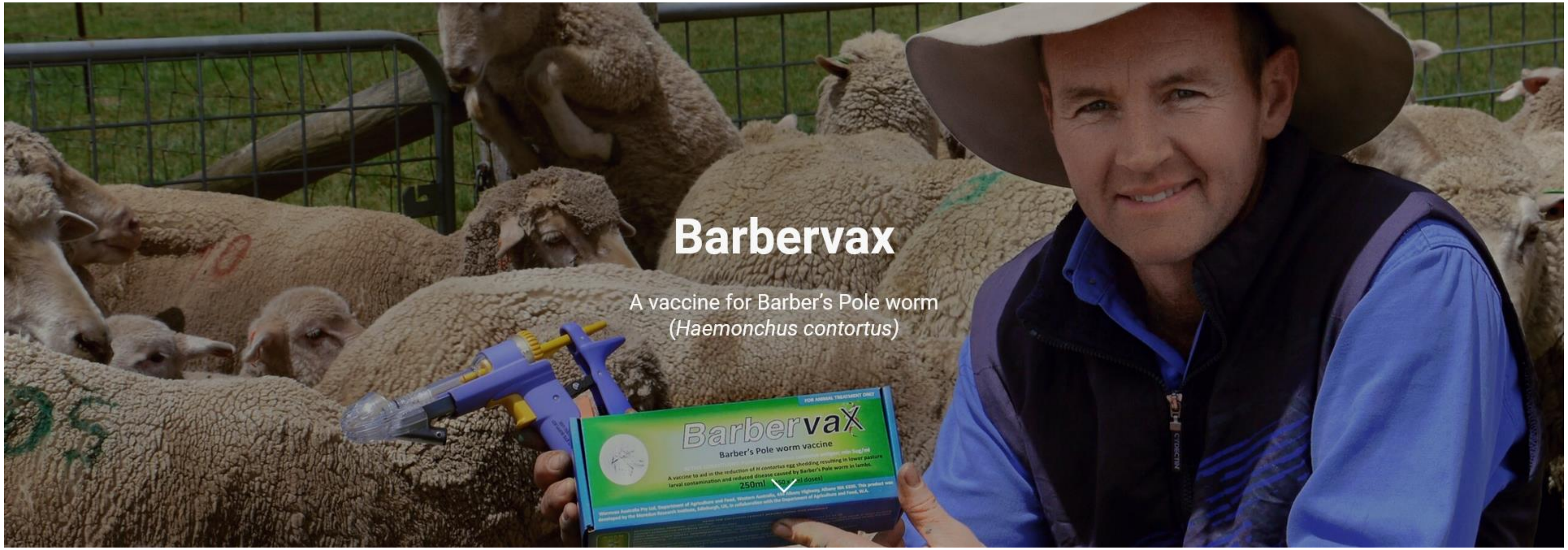
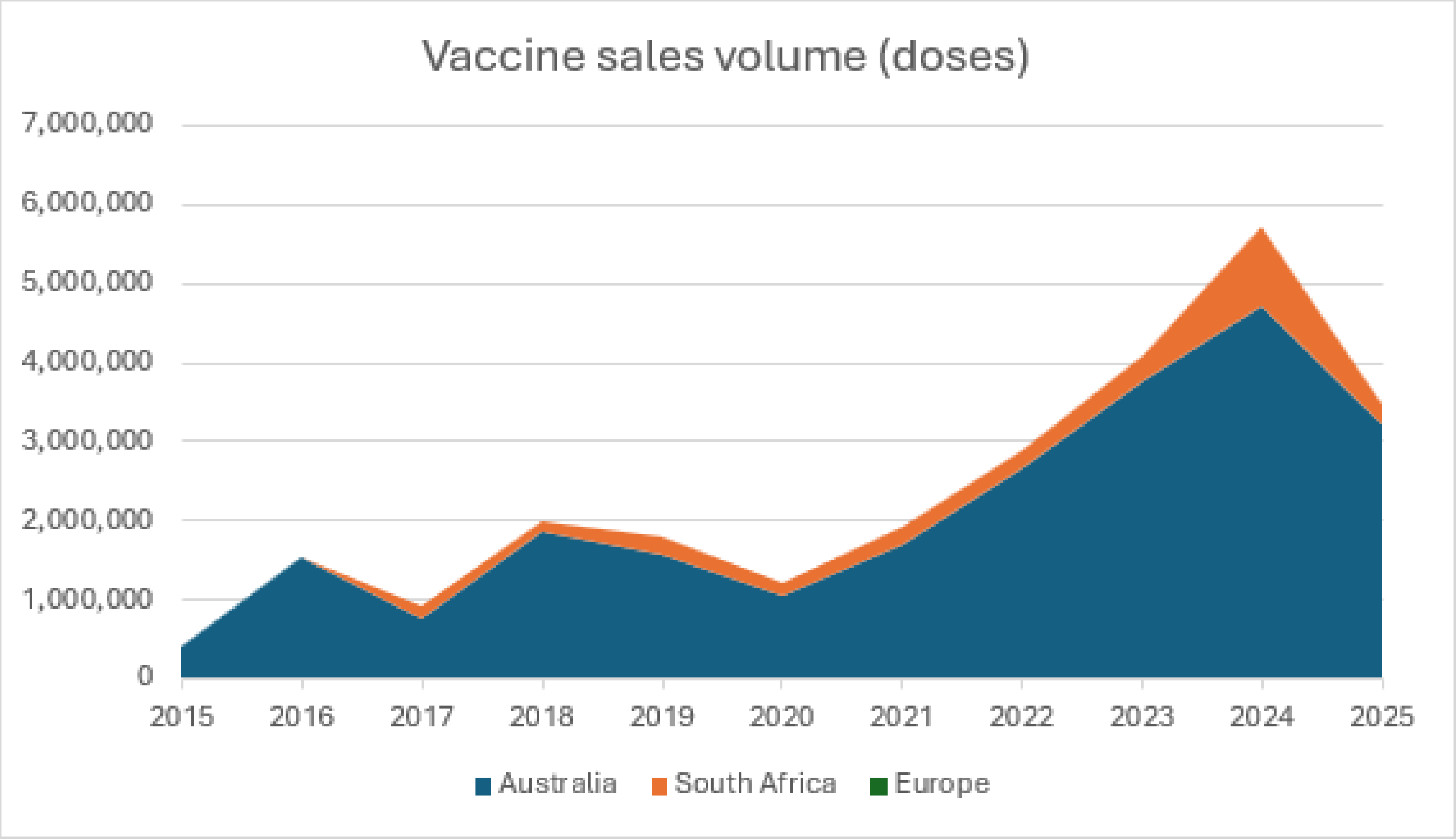


- Manufactured in Australia
- Sold in Australia (Barbervax®)
- South Africa (Wirevax®)
- And the UK (under a Special Treatment Certificate and veterinary prescription)

Barbervax

Barbervax® sales

Moredun



Complex manufacturing process means scale up difficult → demand is outstripping supply

Barbervax

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AbWorm: Development of a synthetic, cheap and easy-to-produce *Haemonchus contortus* vaccine **for global use**

Gates Foundation

H-gal-GP complex: a protective structural antigen of Barbervax®

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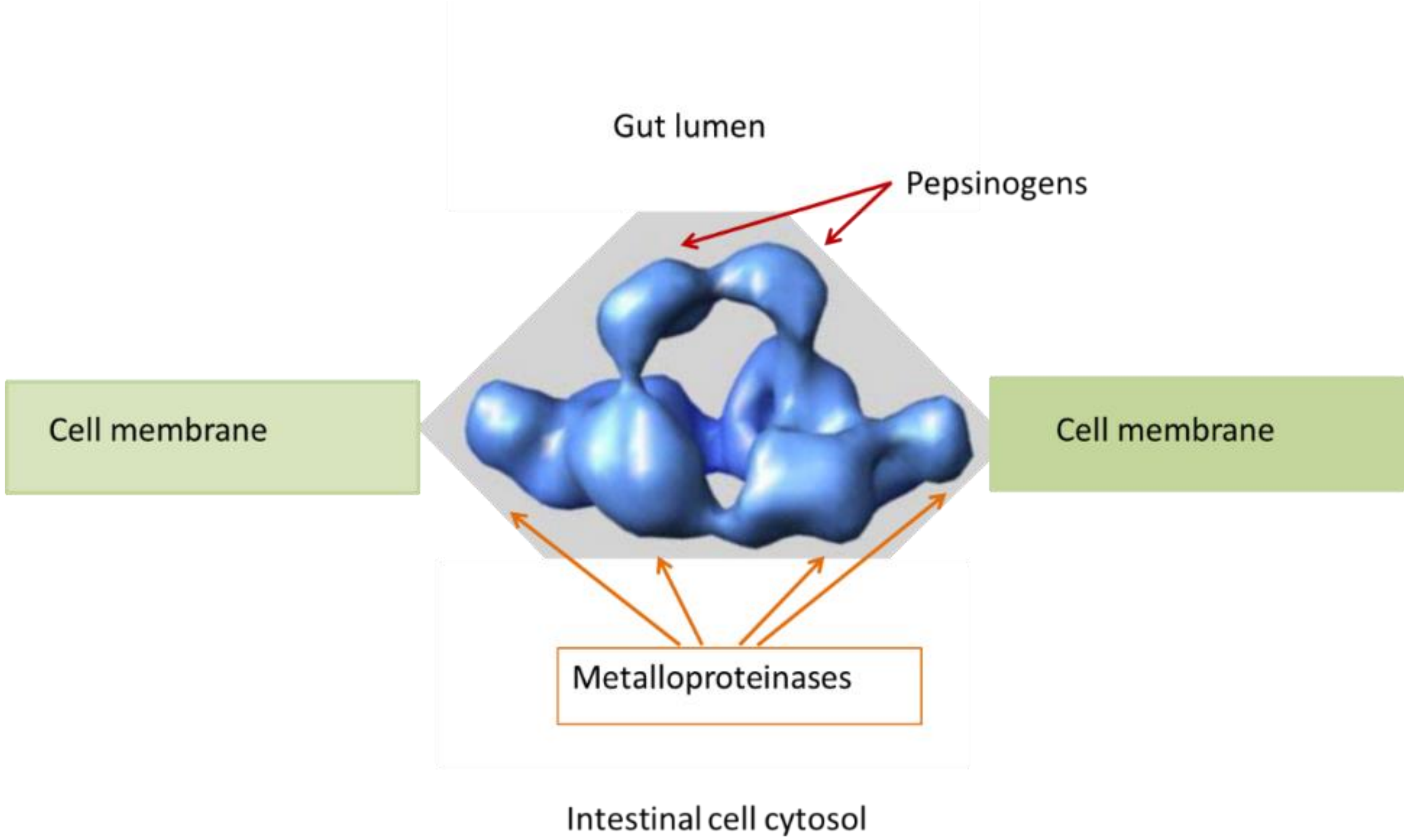
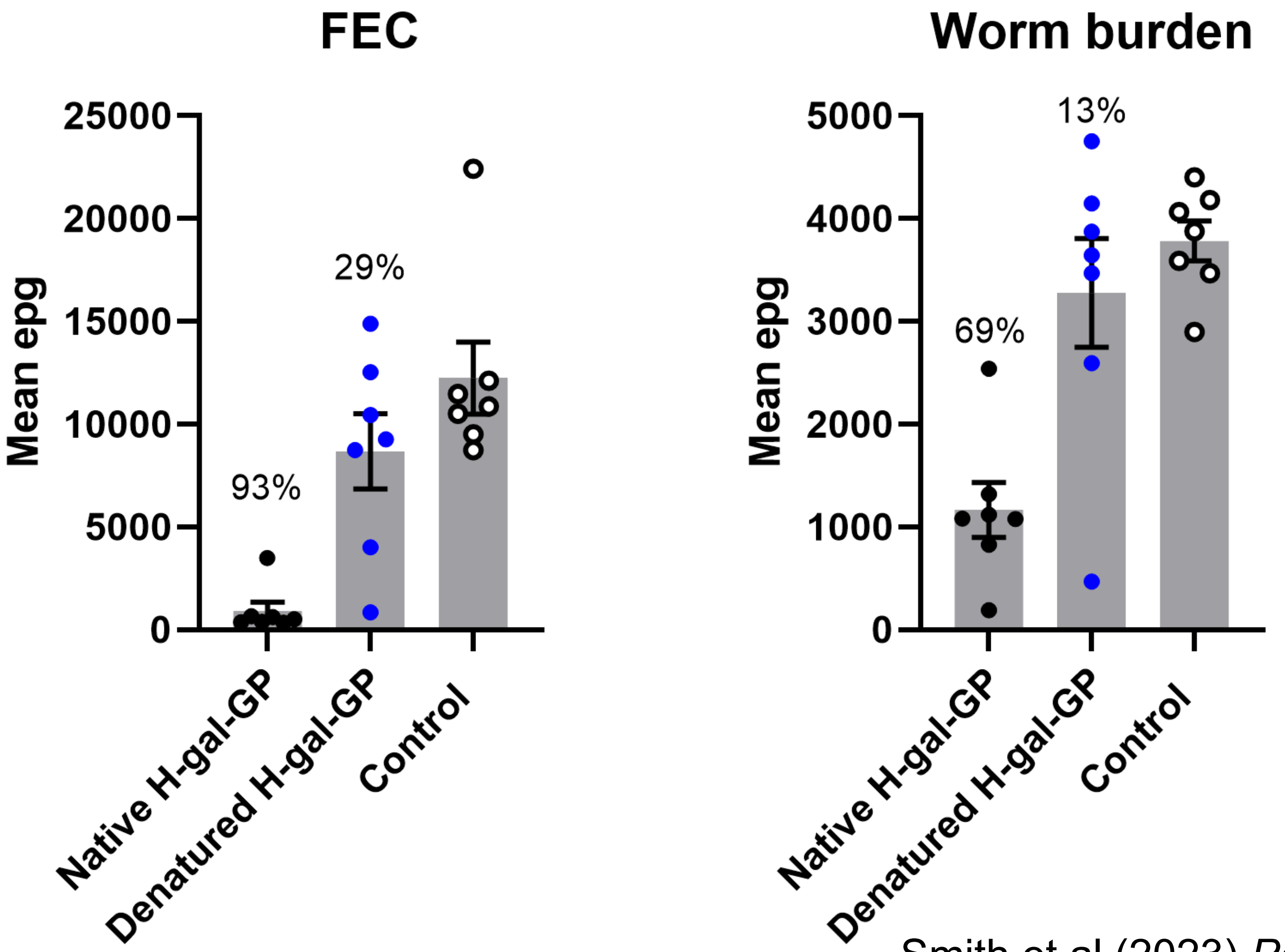
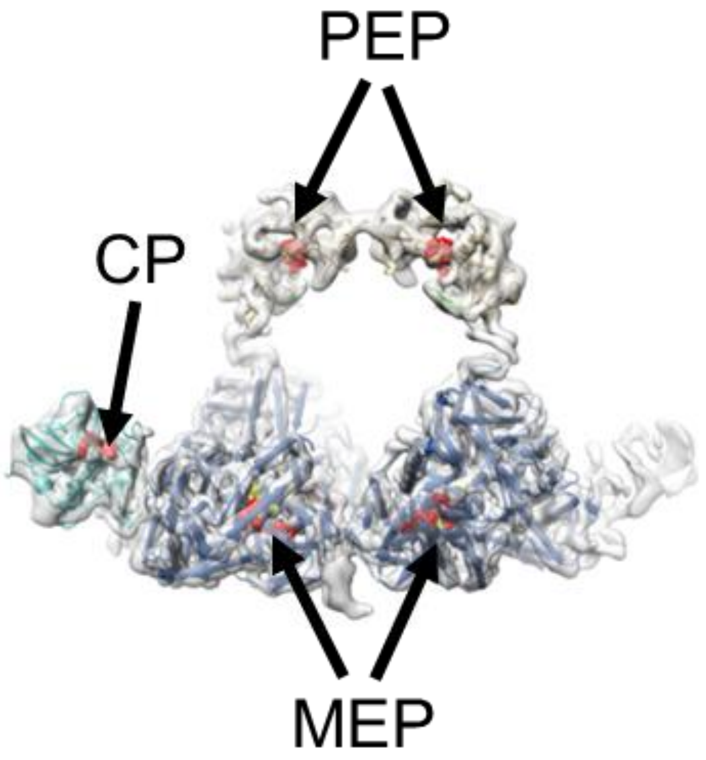


H-gal-GP complex: a protective structural antigen



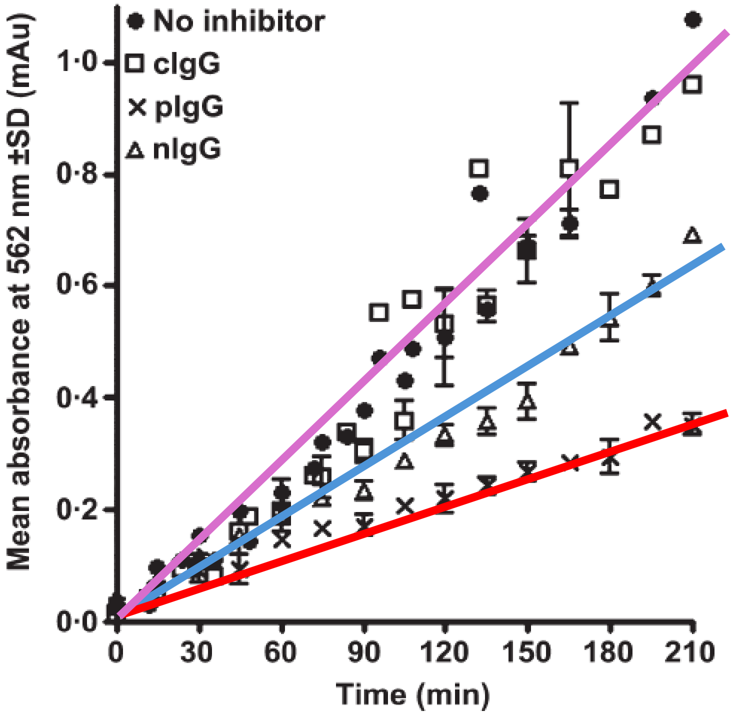
Smith et al (2023) *Parasite Immunology* 25, 313–323

Protection thought to be mediated by serum IgG binding to H-gal-GP which inhibit digestive function



Scarff et al 2020

Antibody-mediated Inhibition of Haemoglobin digestion by H-gal-GP



Ekoja & Smith 2010

cIgG = control IgG (0%)

pIgG = protective IgG from sheep immunized with native H-gal-GP (93%)

nIgG = non-protective IgG from sheep immunized with denatured H-gal-GP (29%)

Protection thought to be mediated by serum IgG binding to H-gal-GP which inhibit digestive function

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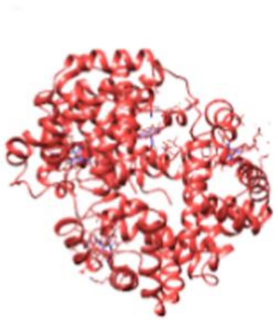
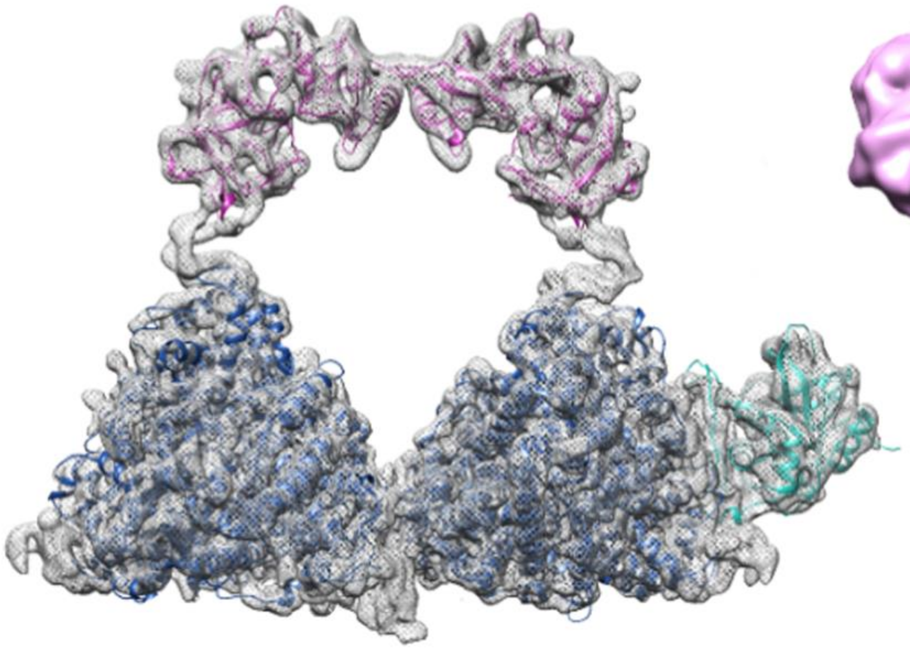
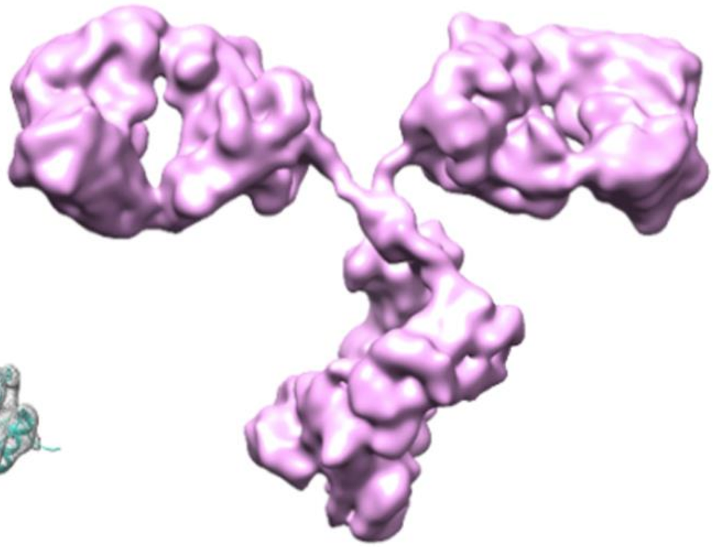
Haemoglobin



H-gal-GP



Antibody



https://doi.org/10.1371/journal.ppat.1008465.s003

AbWorm Phase 1: identify protective anti-H-gal-GP antibodies (Years 1-3)

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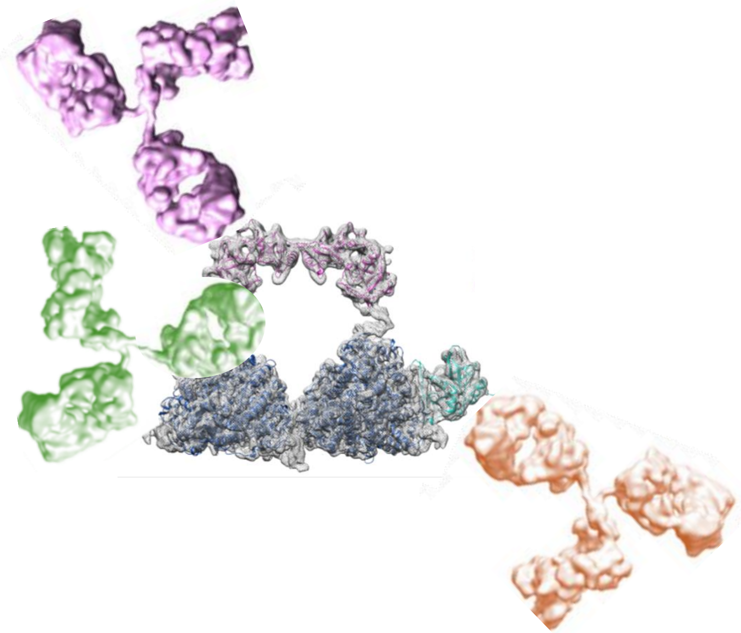
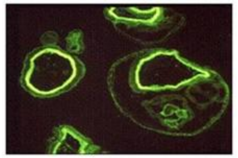
GENERATE SHEEP MONOCLONAL ANTIBODIES

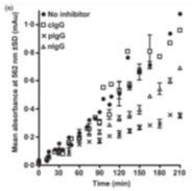


Antibody HUB PIRBRIGHT

FUNCTIONAL ANTIBODY ANALYSIS



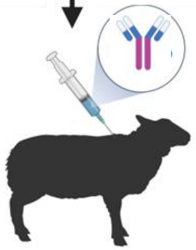
Worm gut binding



Enzyme inhibition

Decreased worm viability

In vitro



Passive immunisation and challenge

In vivo

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AbWorm Phase 2: Generate a mimotope-based synthetic vaccine (Years 4-5)

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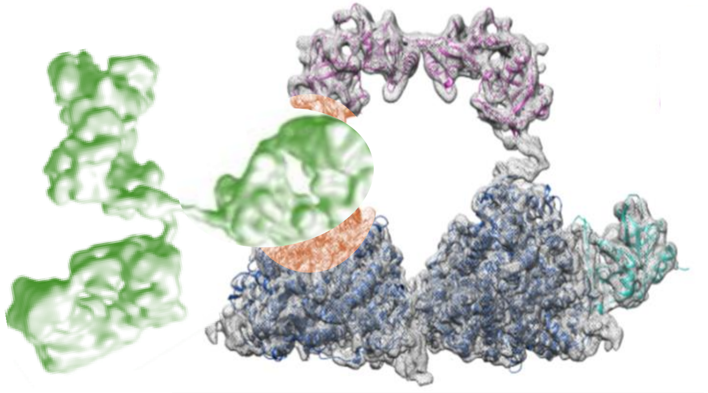
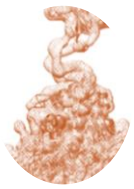
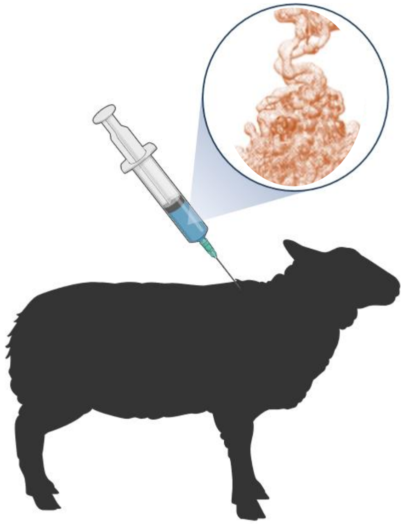


Determine binding site of protective antibodies



Synthetically engineer binding site shape



Mimotope-based vaccine

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Moredun Research Institute
Tom McNeilly
Al Nisbet
David Smith
Phil Steele
Antonela Schiavone
Yolanda Corripio-Miyar
Kevin McLean
Dorota Androscuk

Moredun Research Institute

Gates Foundation
Léna Halos
Meredith Emerson

Gates Foundation

BS & FJ Foster
Ben Foster

The Pirbright Institute
Marie Di Placido
Lucia Gaetani
John Hammond

The Pirbright Institute

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Industry Perspective

Robin Manning

British Agricultural Bureau

Heather Kelman

Food Standards Scotland

Lucinda Bruce-Gardyne

Edinburgh New Town Cookery

David Thomson

Food and Drink Federation Scotland

Andrew Connon

National Farmers Union Scotland

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