Opportunities in agriculture

19-11-20
ZWS Workshop: The Future of Food: Unlocking the benefits of Scotland's Circular Bioeconomy

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Overview

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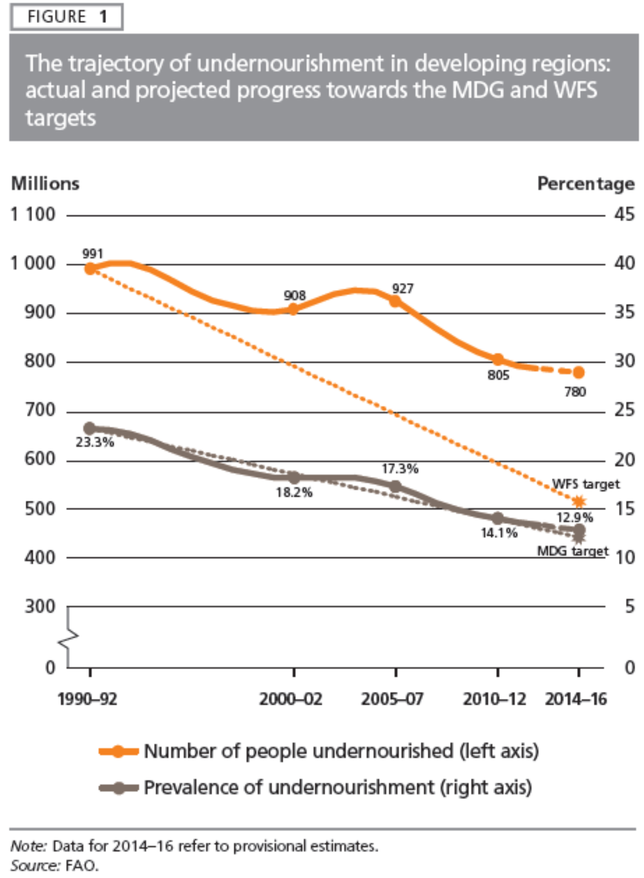
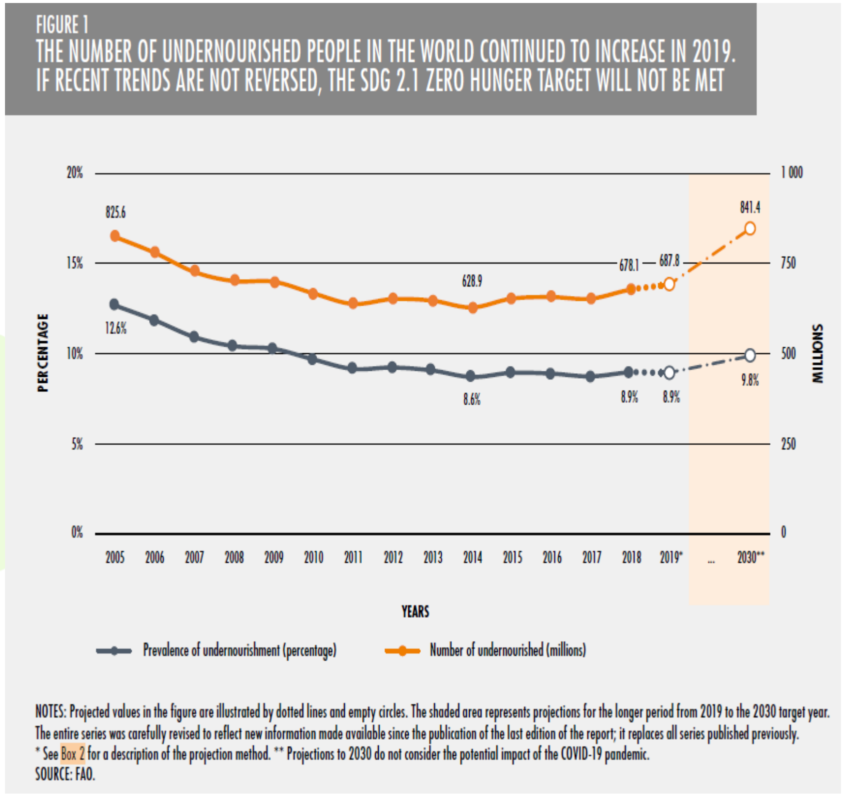
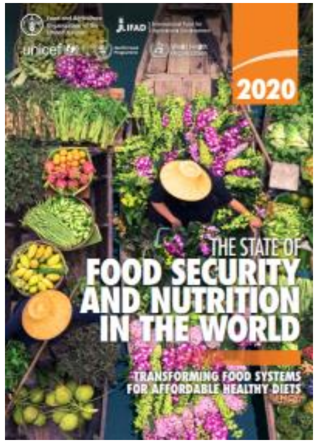
- Background to REES (Rural Economy, Environment and Society Group)
- Examples of our work
  a) What are the main biomaterial flows in Scottish cattle supply chains?
  b) Could insects be used to convert waste into salmon feed?
  c) How can we reduce enteric methane from ruminants?

Trends in undernourishment



Source: FAO (2015, p9), FAO et al. (2020)

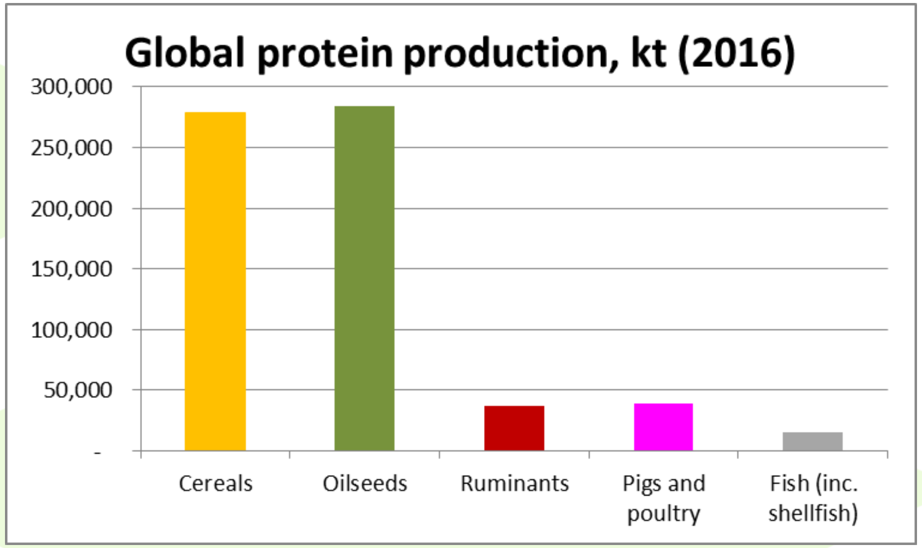


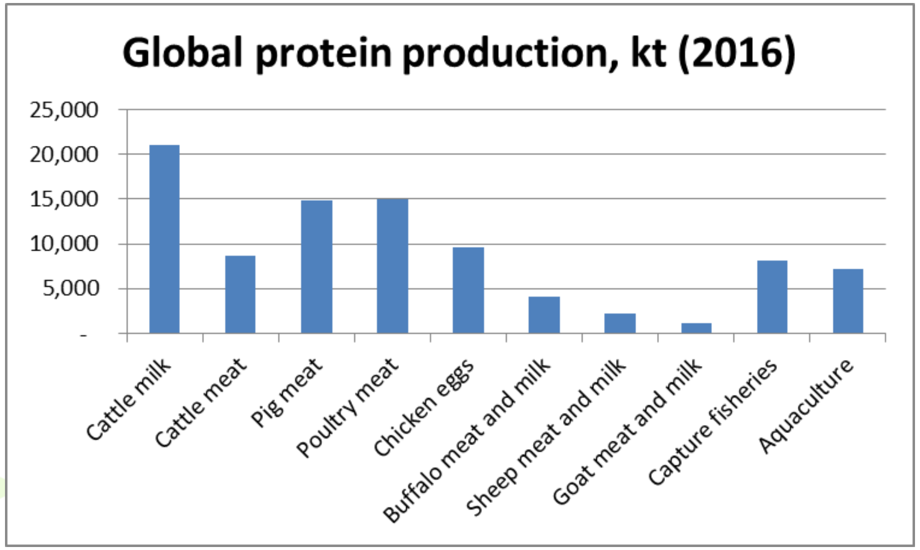


http://www.fao.org/documents/card/en/c/ca9692en

1. Great progress was made 1990 - 2010.
2. Progress has stalled since 2010 (conflict, climate variability and economic downturns).
3. How can we reduce food insecurity while sustaining the natural resource base?

What does the world eat?





Source: FAOstat and OECD-FAOstat Agricultural Outlook data 2018, accessed October 2018.
global protein production Oct 2018.xlsx

- Crops are the main source of macronutrients.
- Livestock commodities are a key element in our diet.
- Global demands for all livestock commodities are increasing, especially poultry, dairy and farmed fish - how do we avoid increases in impacts?

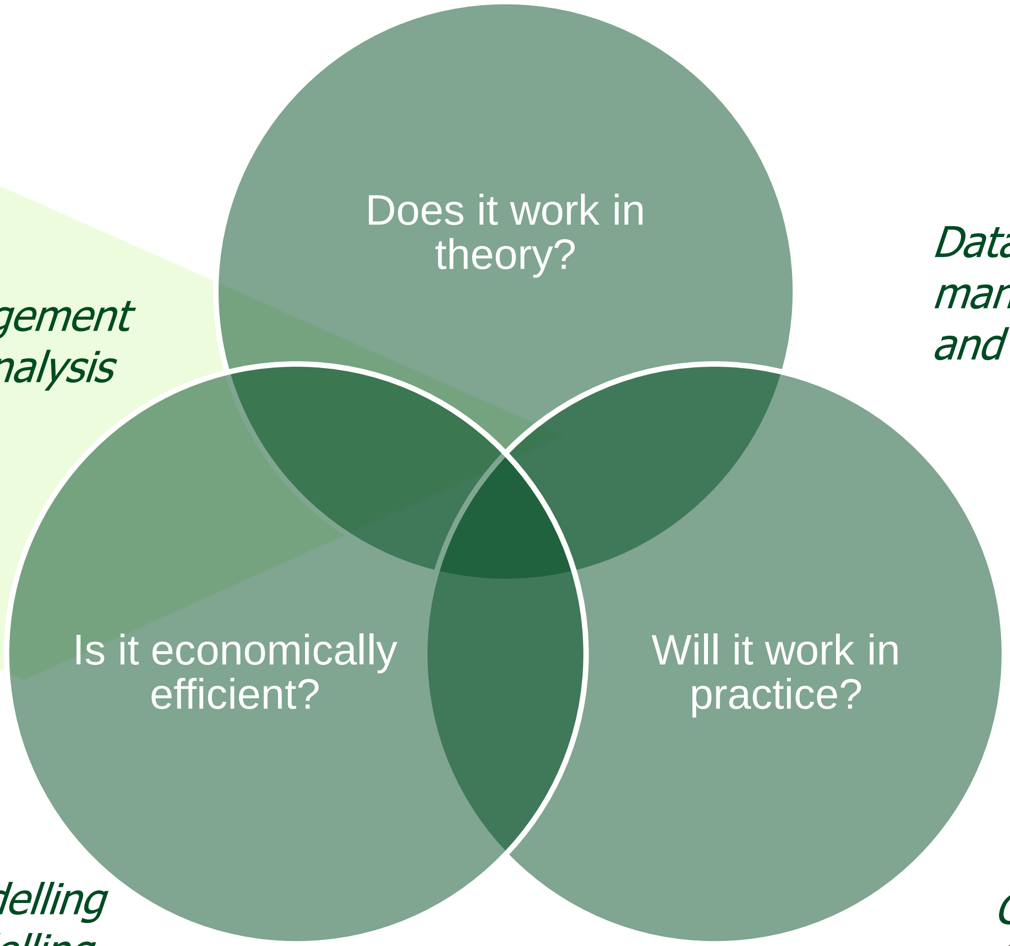
Three key questions we ask when appraising a mitigation measure

Agri-environmental modelling
Life-cycle analysis

Natural scientists

Data management and analysis

Data management and analysis



Macroeconomic modelling
Microeconomic modelling
Cost-benefit analysis
Cost-effectiveness analysis

Economists

Behavioural scientists

Choice experiments
Social surveys
Q methodology

Why are we interested in a circular bioeconomy?

- We're not necessarily…the goal is optimal use of resources in support of economic growth, efficiency and equity.
- In theory, properly functioning markets allocate resources better than scientists (or politicians…) so what's our role?
- Helping to address market failure, e.g.
  - (positive and negative) externalities
  - Imperfect information

Examples of market failure

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Issue	Underlying cause
Under-utilisation of leguminous crops to fix N (instead of synthetic N fertiliser).	Negative externality: i.e. the greenhouse gases emitted during fertiliser production and use are not fully reflected in the price of fertiliser or crops.
Under-investment by farmers in certain animal health interventions.	Positive externality: some of the treatment benefits (e.g. animal welfare, human health) are not captured in the prices received by the farmer.
Overuse of non-recyclable plastic drink containers.	Negative externality: environmental and health impacts of plastic pollution. Informational failure: the purchaser has limited information on the impacts of plastic containers.
Disposal of crops that fail to meet retailer product specifications.	Negative externality: negative environmental impacts of agricultural production. Consumer perceptions and concentration of market power leading to a lack of competition and alternative routes to market.

a. Biomaterial flows in cattle systems

- What: analysing flows on biomaterials in Scottish cattle systems.
- Why: key systems in terms of resource flows and economic importance.
- How: developed a model that calculates the main biophysical flows for different production systems.


THEME 2: PRODUCTIVE AND SUSTAINABLE LAND MANAGEMENT AND RURAL ECONOMIES

RESAS
Rural & Environment Science & Analytical Services

The Scottish Government
Riaghaltas na h-Alba

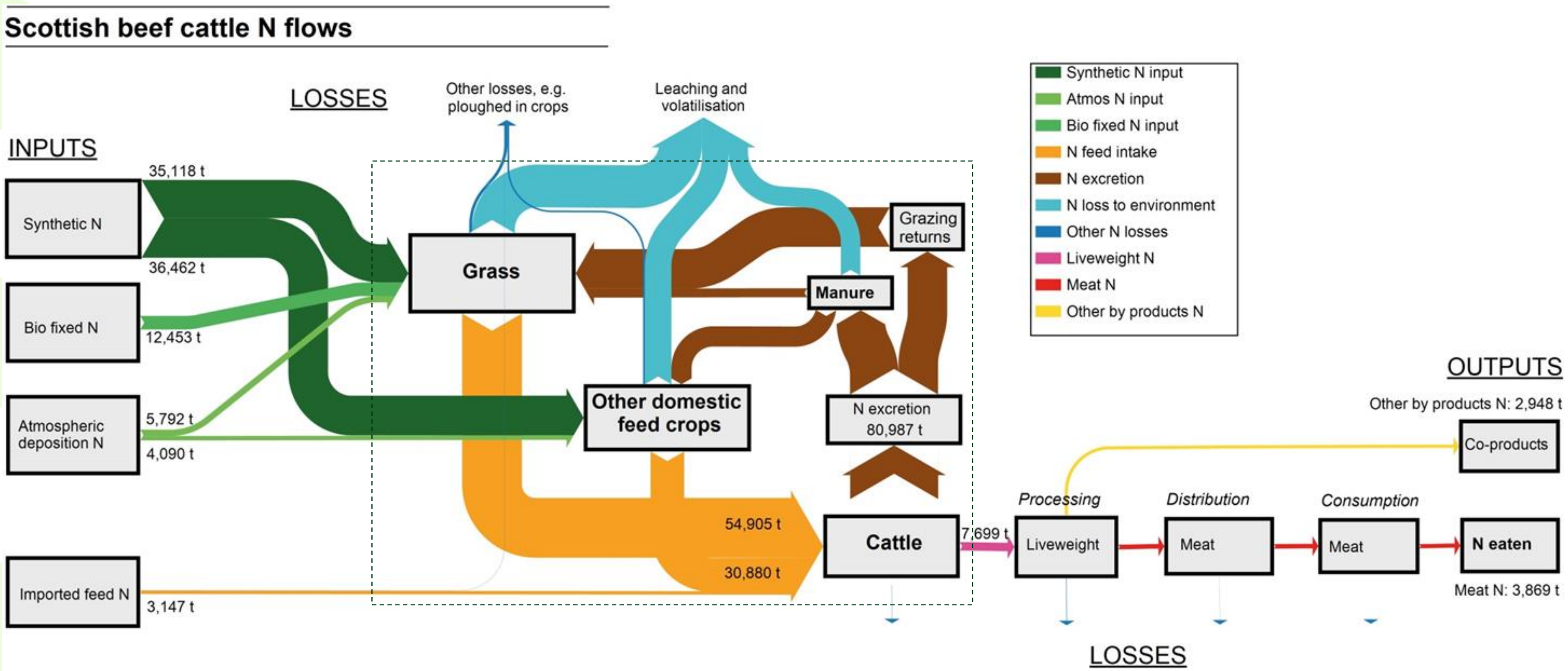
SCOTTISH GOVERNMENT
RURAL AFFAIRS, FOOD AND ENVIRONMENT PORTFOLIO

STRATEGIC RESEARCH PROGRAMME
1 April 2016 to 31 March 2021

Submission
Theme 2 – Productive and Sustainable Land Management and Rural Economies

On behalf of
Scotland's Rural College
James Hutton Institute
Moredun Research Institute
Rowett Institute of Health and Nutrition
Biomathematics and Statistics Scotland
Royal Botanic Garden Edinburgh

Resource flows in the beef supply chain, 2015 – shown in terms of mass of N

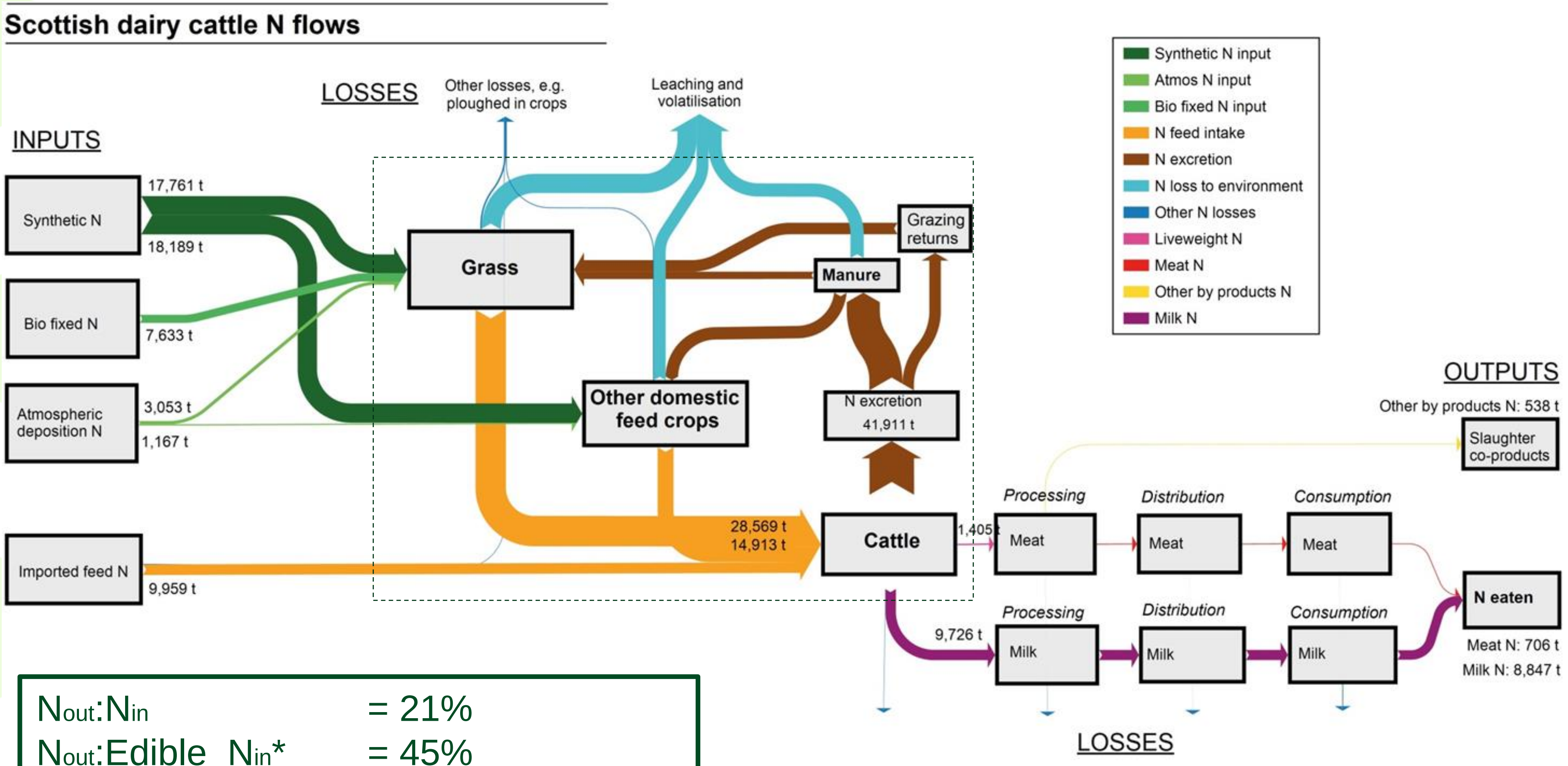


$N_{out}:N_{in}$ = 9%

$N_{out}:Edible\_N_{in}$* = 21%

**N out as a % of human edible feed N in. Human edible feed N is defined as crops that could be used as human food, or are produced on land that could be used to grow human edible crops*

Resource flows in the dairy supply chain (2015) – shown in terms of mass of N



N_{out}:N_{in} = 21%

N_{out}:Edible_N_{in}* = 45%

**N out as a % of human edible feed N in. Human edible feed N is defined as crops that could be used as human food, or are produced on land that could be used to grow human edible crops*

Notes

- Losses post-farm are relatively small compared to those on-farm. However, this is partly an artefact of the units used.
- Expressing the flows in the common unit of mass of N means that we are not directly comparing like with like. Meat N (in protein) at the point of consumption is quite different, physically and economically, to other types of N, e.g. liveweight, plant or synthetic fertiliser.
- As we move down the supply chain, value is added and the cost of each kg of N lost increases, in terms of the financial value and the embedded emissions.

b. Using insects to valorise waste

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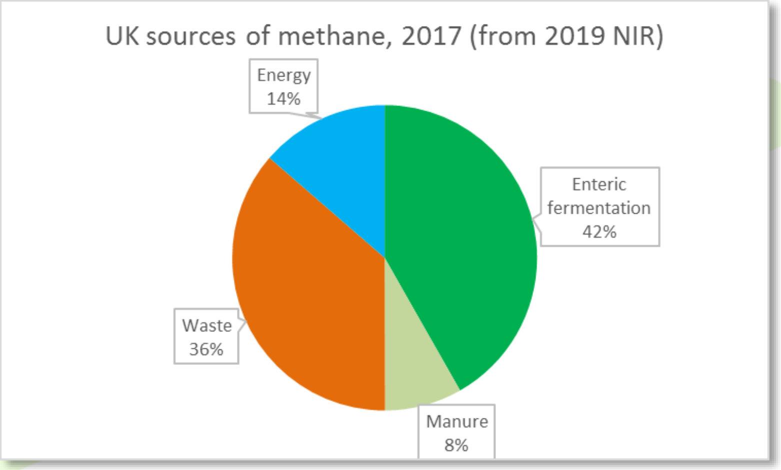
Popoff et al. (2017) investigated attitudes towards the use of insect-derived materials in Scottish salmon feeds

- Insect meal could technically replace fishmeal in salmon rations
- Attitudes of consumers, salmon farmers, feed producers and retailers investigated via semi-structured interviews
  - Consumer attitudes favourable (vegetable waste the preferred feedstock)
  - Farmers and feed producers open-minded to insect meals
  - Retailers expressed reservations
  - Producing insect meal in sufficient quality and quantity at a competitive price challenging
  - While consumer attitudes are favourable, other factors more likely to influence purchasing decisions.

c. Reducing enteric methane

- Methane accounted for 11% of UK GHGs in 2017.
- 3 sectors responsible: agriculture, waste and energy.
- Agricultural methane (CH_4) arises mainly from the anaerobic decomposition of organic matter during enteric fermentation and manure management.



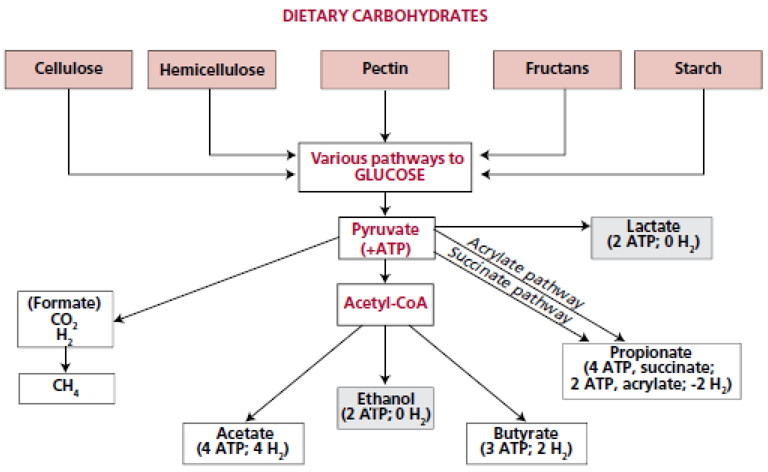
Volta identified methane in 1776
https://en.wikipedia.org/wiki/Alessandro_Volta#/media/File:Alessandro_Volta.jpeg

- In Scotland, most agricultural CH_4 comes from enteric fermentation: beef cattle > sheep > dairy cattle.

Enteric methane

- Ruminants can't digest cellulose, instead microbes in the rumen ferment the cellulose producing volatile fatty acids, which the ruminant then digests.
- This process also produces methane.
- Further details in Hristov et al. 2013, e.g.:

FIGURE 3
Carbohydrate metabolism in the rumen



Source: simplified from Van Soest, 1994 and Russell and Wallace, 1997.

Drivers of Enteric CH_4

- The amount of CH_4 produced *per unit of output* depends on:
  - Feed intake
  - Rate at which the feed is converted to methane ("methanogenesis")
  - Animal output (milk secreted, LWG, offspring)
- Ratio of feed intake to animal output (FCR). Influenced by a wide range of factors: feeding, genetics, management and health.
- Rates of methanogenesis. Also affected by a range of factors, such as rumen ecology, which is in turn affected by: feeding, genetics, health (and treatments).
- Basically, lots of interacting factors – complex, but also means that there are many points at which we can attempt to influence the amount of CH_4 produced.

Enteric methane

Options for reducing enteric methane include:

Measure	Likely to provide large AP?	Why?
Cattle breeding	Yes	Productivity improvement and reduction in CH4 yield. Reduction in dairy cow numbers has knock-on effects on beef sector.
Improved livestock health	Yes	Growing evidence that productivity improvements will reduce emissions intensity
Precision feeding	Possibly	AP modest, CE potentially low but uncertain
3NOP	Possibly	New measure, but evidence is promising.
High starch diet	Possibly	Can have economic benefits, but converting from grass to maize > impacts on soil.
Plant extracts	Probably not	The effects on methane yield and animal physical performance have yet to be confirmed with long-term in vivo experiments.
Biodiverse swards	Probably not	May reduce methane yield, but risks of impacts on animal performance. Biodiversity benefits

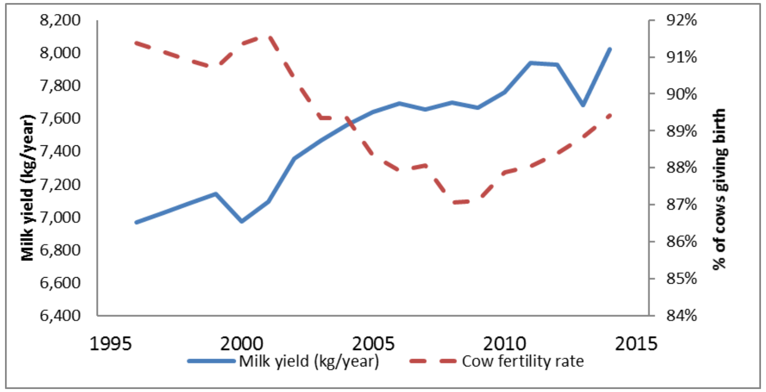
AR: Abatement rate *AP: Abatement potential* *CE: Cost-effectiveness* *SCC: Social Cost of Carbon*

Example: cattle breeding

Mitigation summary	
Likely to provide large AP	Yes
Confidence in mitigation effect	High
Cost-effectiveness	Low
Confidence in cost-effectiveness	High

- Breeding can reduce emissions intensity in a number of ways:
  - Conventional breeding goals (e.g. milk yield, growth rate)
  - Selecting animals with lower rates of methane production
- Significant scope for increased uptake of improved genetics, particularly in beef and sheep sectors.
- Should lead to reduction in EI at negative/low cost

- Need to avoid negative impacts
- Unintended consequence - reduction in dairy beef production



Trends in Scottish dairy cow milk yield and fertility (based on data in CDI 2016).

Example: 3NOP (3-nitrooxypropanol)

Mitigation summary	
Likely to provide large AP	Possibly
Confidence in mitigation effect	moderate
Cost-effectiveness	moderate
Confidence in cost-effectiveness	low

- 3NOP is a chemical that reduces the excretion of enteric methane by ruminants when added to their rations (or introduced via a bolus). It does so by reducing the rates at which rumen archaea convert the hydrogen in ingested feed into methane.
- New mitigation measure (it was patented in 2012), but a range of experimental studies and meta-analyses have been undertaken. Meta-analysis concluded: "3-NOP is an effective feed additive to mitigate enteric CH4 emissions without compromising productive performance of ruminants." Javanegara et al. (2017).
- Studies indicate that cattle enteric methane by could be reduced by 20-30% > very large abatement potential (in theory).
- 3NOP not yet approved for commercial use, so CE unknown, but could be below SCC.
- "Further studies are required to assess carry-over of the compound into animal products and food safety concern when the products are consumed by human." Javanegara et al. (2017).

Example: Plant extracts and more biodiverse swards

Mitigation summary	
Likely to provide large AP	No
Confidence in mitigation effect	Low
Cost-effectiveness	Extracts: moderate. Swards: uncertain - depends on effects on animal performance
Confidence in cost-effectiveness	Low: effectiveness uncertain

- “A wide range of plant secondary metabolites (chemicals not involved in primary metabolic functions such as growth and reproduction) have been shown to have the potential to modulate the fermentation process in the rumen” Jafari et al (2019).
- Most of these can be classified into three groups: saponins, tannins and essential oils (EO). These substances can be extracted from plants and added to feed (EO) or by grazing more species rich swards that increase tannin/saponin content.
- EO: products are commercially available, however the effects on methane yield are mixed - long-term in vivo experiments required.
- Swards: studies reported a reduction in methane yield, but also concerns about the risk of impact on animal performance (milk yields and growth rates).
- Ancillary benefits in terms of biodiversity.
- EO may become more important as use of antibiotics reduces.

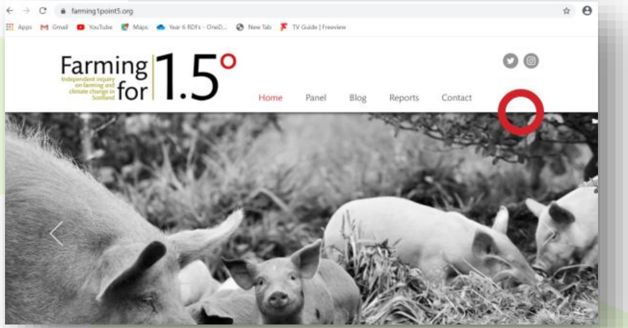
Example: improving livestock health

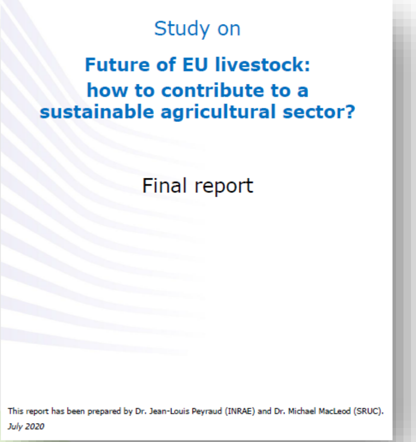
Mitigation summary	
Likely to provide large AP	Yes
Confidence in mitigation effect	Moderate
Cost-effectiveness	Low-moderate
Confidence in cost-effectiveness	Moderate

- Health can be improved through preventative controls (such as changing housing and management to reduce stress and exposure to pathogens, vaccination, improved screening and biosecurity, disease vector control) and curative treatments such as antiparasitics and antibiotics.
- The emissions intensity of ruminant meat and milk production is sensitive to changes in key parameters influenced by health status, such as: maternal fertility rates, mortality rates, milk yield, growth rates and feed conversion ratios.
- 2015 MACC estimated that improving health could reduce emissions by up to 1.4MtCO2e (cattle) and 0.5MtCO2e (sheep), at low/moderate cost.
- Studies undertaken since 2015 do not contradict the above findings.
- Specific examples of how the abatement potential might be achieved include: reducing the incidence of gastrointestinal parasites, liver fluke and lameness.
- Potential barriers include:
  - Resistance to treatments (e.g. antimicrobial, anthelminthic).
  - Medicine residues in meat and milk, and associated withdrawal periods.
  - Need for co-ordinated action to achieve effective treatment.

Future of livestock

Lots of ideas out there…




Study on

Future of EU livestock: how to contribute to a sustainable agricultural sector?

Final report

This report has been prepared by Dr. Jean-Louis Peyraud (INRAE) and Dr. Michael MacLeod (SRUC).

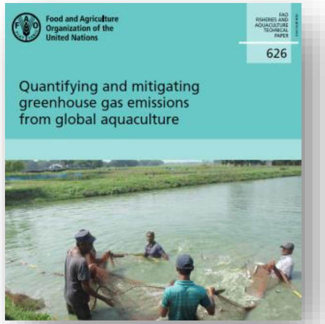
July 2020

"The sustainability of livestock could be improved through efficiency gains, substitution of high impact inputs with lower impact alternatives or via more fundamental redesign of agricultural systems involving shifts from linear approaches to circular approaches." (Peyraud and MacLeod 2020, p48).

On aquaculture:

http://www.fao.org/3/ca7130en/ca7130en.pdf

https://www.nature.com/articles/s41598-020-68231-8



Conclusions

- REES have methods to answer questions such as:
  - What is the magnitude and location of particular biomaterials?
  - What is the total life cycle impact of different technologies?
  - What is the financial performance of different technologies
- Circularity is not the only tool in the box – start with a tangible goal *then* identify the best means of achieving it.
- Have a clear rationale when seeking government support – there is an opportunity cost to govt time and money.
- Bear in mind unintended consequences.
- Get in touch if you would like to know more about what we do (or have an idea for an MSc project!)

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Acknowledgements

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