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The Potential of Cellular Agriculture to Reduce Environmental Impacts of Food Systems

Tuomisto, Hanna

2019

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2019

Livestock, Environment and People (LEAP) Conference



Saïd Business School, Oxford
10th December 2019

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CONFERENCE SPONSOR

Wellcome Trust's Our Planet Our Health



“Since 2015, we've supported a community of researchers who are taking on the challenges that food systems, increasing urbanisation and climate change pose to our health. We aim to stimulate research excellence and develop global collaborations to drive change”

WELCOME

We are delighted to welcome you to Oxford for the second Livestock, Environment and People (LEAP) Conference. LEAP, a project funded by the Wellcome Trust as part of their Our Planet Our Health initiative, is a partnership between Oxford University, the International Food Policy Research Institute, The Nature Conservancy and Sainsbury's. Its goals are to study the health, environmental, social and economic effects of meat and dairy production and consumption and aims to provide evidence and tools for decision makers to help them promote healthy and sustainable diets.

We are lucky to have two excellent plenary speakers again this year, Professor Corinna Hawkes, City, University of London, and Professor Andrew Balmford, University of Cambridge who we thank for generously sharing their time and expertise. At the heart of this meeting are the people who submitted abstracts and we are delighted to welcome all our contributors from across the UK and beyond. We hope that the range of topics will provide a stimulus for interdisciplinary discussions and perhaps the start of new collaborations, leading to a network of researchers focused on the role of meat and dairy in future food systems.

We would welcome your feedback on the value of the day and encourage you to email any of the LEAP team.

On behalf of the whole LEAP team, thank you for joining us and we hope that you will have an interesting and rewarding day.

With best wishes,

Professor Susan Jebb

Co-Director of LEAP



Professor Sir Charles Godfray

Co-Director of LEAP



KEY INFORMATION



Venue

Saïd Business School, Park End Street, Oxford, OX1 1HP ([Click here for further details](#))



Registration

from 09:15-10:00 am on the 10th December 2018 in the Saïd Business School foyer



Catering

Refreshments, lunch and a drinks reception will be served in the foyer.



Wifi

Please use either Eduroam or 'the cloud' <http://service.thecloud.net> and set up a username and password (*the cloud is an unsecure browser)



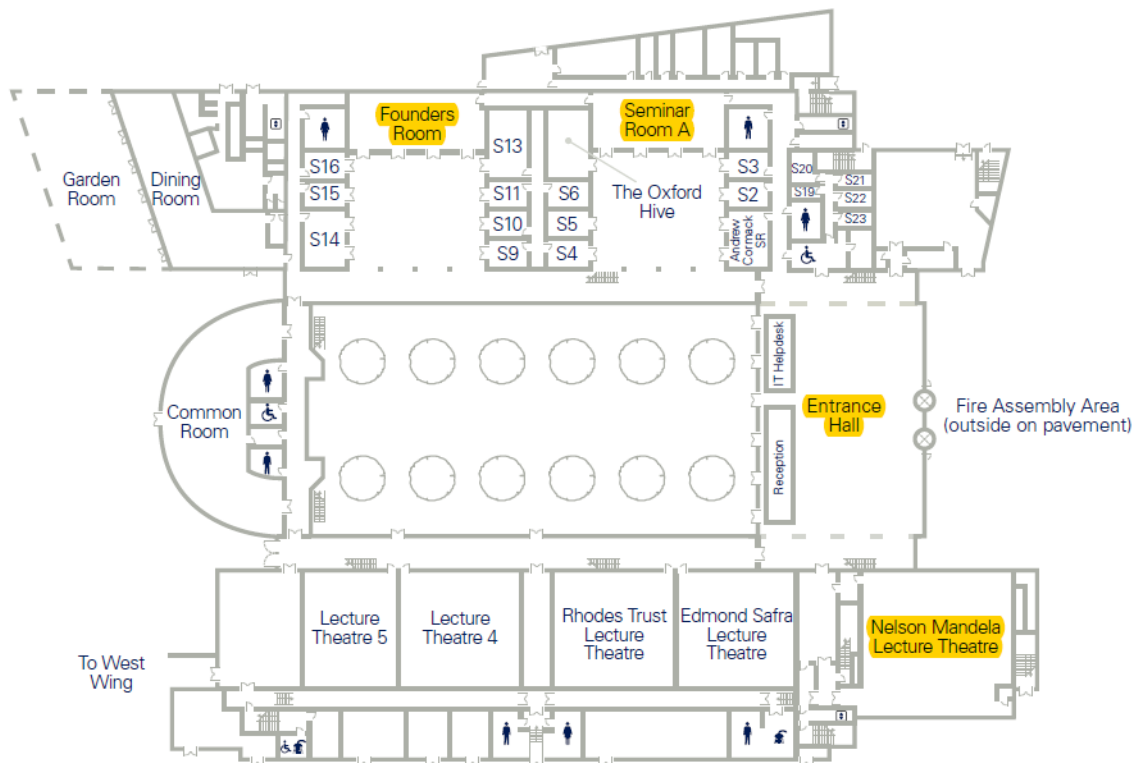
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#OxLeap19

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LEAP photographers and videographers will be in operation. If you do not wish to be included please let a LEAP member know. You are welcome to take your own photo's, except where this sign is indicated.



Lift



Toilets

Map of the Saïd Business School, Oxford [LEAP19 located in yellow rooms]

PLENARY SPEAKERS

What will work to help the world to eat differently?

For the health of people and planet, the worlds 7.7 billion people need to eat differently. Addressing stunting, wasting, underweight, micronutrient deficiencies, obesity, non-communicable diseases and the environmental impact of food production will involve eating more of the right kind of food and fewer foods with negative health and environmental consequences

In her presentation, Professor Hawkes will outline the nuts of bolts of what it will take to help the world eat better diets. Taking a people-centred approach, she will show what needs to change about our lives and the food system that serves us to give us all the ability and willingness to eat differently. These include changes to our knowledge, skills, income, assets, capacity, social relationships, access, exposure, and preferences, combined with redesigning the structure and functioning of the modern food system. In this context, Professor Hawkes will assess how far the current landscape of policies and interventions has come and identify what is missing. The presentation will end by drawing conclusions for the research and evidence needed to inform the transition to a world that eats differently.



Professor Corinna Hawkes

Professor of Food Policy, Director of Centre for Food Policy, City, University of London

Professor Hawkes is Director, Centre for Food Policy, City, University of London and a Distinguished Fellow at the George Institute for Global Health. She has worked with UN agencies, governments, universities and NGOs for 20 years to advance effective policies to improve diets and reduce malnutrition and non-communicable diseases, including the World Health Organization, the International Food Policy Research Institute, the University of Sao Paulo and World Cancer Research Fund International, where she established the NOURISHING Framework to monitor healthy eating policies worldwide. Corinna was a Commissioner on the Lancet Commission on Obesity and the Eat-Lancet Commission on Healthy Diets from Sustainable Food Systems. Between 2015-2018 she was Co-Chair of the Global Nutrition Report and in 2018 was appointed Vice Chair of the London Child Obesity Taskforce.

Feeding the world without costing the earth

How we choose to deal with rising human food demand will to a large degree determine the state of biodiversity and the wider environment in the 21st century. Andrew's talk will start by setting out recent work examining two routes to reducing demand – making better use of food waste, and lowering meat consumption. The rest of the presentation will focus on two contrasting supply-side approaches to meeting remaining demand at least cost to nature: land sharing, in which farmland is made as friendly to wildlife as possible, albeit at the cost of lower yields; and land sparing, in which space for nature on unfarmed land is maximised by farming elsewhere at high yields. Developing and then parameterising a simple model of the population-level impacts of these alternative approaches shows that across five continents, many biomes, and almost 2000 species, a land-sparing approach consistently outperforms land sharing, particularly for species of highest conservation concern. By slowing habitat conversion or freeing-up farmland for habitat restoration sparing also offers considerable potential for lowering greenhouse gas emissions. These findings raise further pressing questions – about other consequences of high- vs lower-yield farming, how to increase yields while lowering environmental externalities, and how to tie yield increases to setting aside land for nature.



Professor Andrew Balmford

Professor of Conservation Science,
Conservation Science Group, Department of
Zoology, University of Cambridge

Andrew is Professor of Conservation Science at the Department of Zoology, University of Cambridge. His main research interests are exploring how conservation might best be reconciled with area-demanding activities (like farming), quantifying the costs and benefits of effective conservation, and examining what works in conservation. In his book

Wild Hope he argues that cautious, evidence-based optimism is vital in tackling environmental challenges. Andrew helped establish the Student Conference on Conservation Science, the Cambridge Conservation Initiative, and Earth Optimism.

OXLEAP19 CONFERENCE AT A GLANCE

09:15 – 10:00

REGISTRATION

[Entrance Hall]

10:00 – 10:15

WELCOME - Professor Susan Jebb

[Nelson Mandela Lecture Theatre]

10:15 – 11:00

PLENARY SESSION
Professor Corinna Hawkes, City, University of London

[Nelson Mandela Lecture Theatre]
Chair: Professor Susan Jebb

11:00 – 11:25

REFRESHMENTS

[Entrance Hall]

11:25 – 13:00

[SESSION 1 \[Nelson Mandela Lecture Theatre\]](#)

Chair: Dr Marco Springmann

The deforestation footprint of Brazilian beef exports
Erasmus zu Ermgassen et al. (Université Catholique de Louvain)

A systemic and participatory analysis of the commercial broiler industry in South Africa
Kevin Queenan et al. (RVC, University of London)

Demand for animal-source foods: past trends and future drivers
Adam M. Komarek et al. (IFPRI)

The potential of cellular agriculture to reduce environmental impacts of food systems
Hanna L. Tuomisto et al. (University of Helsinki)

The effect of upland pasture management on cattle production
Non G Williams et al. (Bangor University)

Role of livestock in long-term soil health and agricultural productivity
Taro Takahashi et al. (Rothamsted Research)

[SESSION 2 \[Seminar Room A\]](#)

Chair: Dr Brian Cook

EAT-Lancet score and major health outcomes: the EPIC-Oxford study
Keren Papier et al. (University of Oxford)

Household dairy production and child growth: Evidence from Bangladesh
Samira Choudhury and Derek Headey (SOAS, University of London)

Replacing meat with alternative plant-based products (RE-MAP): results of a randomised controlled trial of a behavioural intervention to reduce meat consumption
Filippo Bianchi et al. (University of Oxford)

Using language to increase the attractiveness of plant-based foods
Esther K. Papiés et al. (University of Glasgow)

Shifting Consumer Demand for Plant-Rich Foods: An Intervention Playbook for the Food Service Sector
Sophie Attwood et al. (World Resources Institute)

Vegetarian diets and risks of total and site-specific fractures: results from the prospective EPIC-Oxford study
Tammy Y.N. Tong et al. (University of Oxford)

OXLEAP19 CONFERENCE AT A GLANCE

13:00 – 14:00

LUNCH AND POSTER VIEWING

[Entrance Hall]

14:00 – 15:35

[SESSION 3 \[Nelson Mandela Lecture Theatre\]](#)

Chair: Dr Alexandra Sexton

Consumer Acceptance of Cultured Meat: A Systematic Review

Christopher Bryant and Julie Barnett (University of Bath)

In Search of a Structure to Come: A Meaning System of Cultured Meat in Finland?

Toni Ryyänänen and Anni Toivanen (University of Helsinki)

‘Promising the earth’: the coverage of cultured meat in the US and UK elite media, 2013-18

James Painter et al. (University of Oxford)

How *not* to: reduce food disgust

Maya Gumussoy et al. (University of Bristol)

What’s the beef?: the problematisation of meat eating and sustainable diets

Damian Maye et al. (University of Gloucestershire)

Multiple health and environmental impacts of foods

Michael Clark et al. (University of Oxford)

[SESSION 4 \[Seminar Room A\]](#)

Chair: Dr Christina Potter

Appraising the socio-ecological role of pasture-fed beef - as part of the UK food system and in the context of a warming planet

Claire Waterton and Dr Lisa Norton (Lancaster University)

Food system “tracers” to analyse healthy and sustainable food systems: tracing milk in India

Kerry Ann Brown et al. (LSHTM, University of London)

Environmental effects of livestock production in Europe – exploring regional differences

Marja Roitto et al. (University of Helsinki)

Sustainability of dairy specialization in Ireland depends on land use consequences and diet change context

Rémi Prudhomme et al. (National University of Ireland)

How Bad Is It? A Systematic Review of the Sustainability of Beef Production in Seven Leading European Countries

Lana Repar et al. (University College Cork)

The greenhouse gas impacts of converting livestock farming in England and Wales to organic methods

Laurence Smith et al. (Cranfield University & Royal Agricultural University)

15:35 – 16:00

REFRESHMENTS

[Entrance Hall]

16:00 – 16:45

PLENARY SESSION

Professor Andrew Balmford, University of Cambridge

[Nelson Mandela Lecture Theatre]

Chair: Professor Charles Godfray

16:45 – 18:00

POSTER SESSION AND DRINKS RECEPTION

[Entrance Hall]

PROGRAMME ABSTRACTS

SESSION 1

CHAIR: Dr Marco Springmann

[Nelson Mandela Lecture Theatre]

1. **The deforestation footprint of Brazilian beef exports**
Erasmus zu Ermgassen et al. (Université Catholique de Louvain)
2. **A systemic and participatory analysis of the commercial broiler industry in South Africa**
Kevin Queenan et al. (RVC, University of London)
3. **Demand for animal-source foods: past trends and future drivers**
Adam M. Komarek et al. (IFPRI)
4. **The potential of cellular agriculture to reduce environmental impacts of food systems**
Hanna L. Tuomisto et al. (University of Helsinki)
5. **The effect of upland pasture management on cattle production**
Non G Williams et al. (Bangor University)
6. **Role of livestock in long-term soil health and agricultural productivity**
Taro Takahashi et al. (Rothamsted Research)

THE DEFORESTATION FOOTPRINT OF BRAZILIAN BEEF EXPORTS

zu Ermgassen, E.K.H.J., Godar, J., Löfgren, P., Sikansi, F., Klarman, S., Phare, J., Vasconcelos, A., Gardner, T., Meyfroidt, P.
Université Catholique de Louvain, Belgium

Almost one-third of global deforestation is driven by the production of commodities such as beef, oil palm, soy, and timber. Despite the importance of forests for the United Nations' Sustainable Development Goals, climate mitigation, and biodiversity conservation, commodity-driven deforestation remains challenging to eliminate, not least because these commodities are traded along complex, international supply chains which spatially separate production from consumption. Few sectors have a bigger impact than the Brazilian cattle sector, responsible for one-fifth of all commodity driven deforestation across the tropics. In this study, part of the Trase initiative (<https://trase.earth/>), we map the sub-national origin of and deforestation embedded in Brazilian meat, offal, and live cattle exports for 2015-2017, a trade worth almost \$6 billion annually. Export markets purchase 19% of Brazil's beef, shouldering 13-14% of deforestation risk, between 66,000-75,000 ha each year, releasing 24.2-30.0 Mton of CO₂/year in the process. We link these impacts to 194 exporting companies, 3,017 importing companies and 150 international markets, finding large spatial variation in the origin of sourcing and deforestation risks of different markets and products.

Three companies, JBS, Minerva, and Marfrig, who have each made a zero deforestation commitment for sourcing from the Amazon, handled 68% of Brazil's cattle exports and shouldered 65.3% of export-associated deforestation risk. 51% of this deforestation risk was linked to sourcing of cattle from the Amazon, and 47.2% from the Cerrado, where their commitment does not apply. 30.6%, 12.1%, 10.2%, and 8.3% of exports (by value) went to China, the European Union, Egypt, and Russia, who were exposed to 26.9%, 4.5%, 16.1% and 14.3% of deforestation risk, respectively. We also identify a disproportionate risk associated with the export of live cattle, which represented only 2.5% of exports by value, but were concentrated in the Amazon state of Pará and were linked to 8.7% of deforestation risk. Our results provide an unprecedented insight into the deforestation embedded in international trade and reinforce calls to improve monitoring and the scope of zero deforestation commitments in the Brazilian cattle sector in order to achieve nationwide reductions in deforestation.

A SYSTEMIC AND PARTICIPATORY ANALYSIS OF THE COMMERCIAL BROILER INDUSTRY IN SOUTH AFRICA

Queenan, K., Cuevas, S., Sobratee, N., Mabhaudhi, T., Chimonyo, M., Slotow, R., Shankar, B., Häslér, B.

Royal Veterinary College, University of London

The Sustainable and Healthy Food Systems (SHEFS) programme aims to provide evidence for policy development that delivers nutritious and healthy diets in an environmentally sustainable and socially equitable manner. A literature review and stakeholder system-mapping workshop formed the basis of a conceptual system dynamics (SD) model of the livestock-derived food (LDF) system of South Africa. This highlighted the key structural elements, the linkages to the environment, nutrition and health, and the growing predominance of commercially produced broilers. Subsequently, a whole-system and transdisciplinary analysis of the South African commercial broiler system was initiated. Methods include a scoping literature review, identification and interviewing of key stakeholders and group model building of a broiler SD model.

Per capita broiler meat consumption more than doubled from 1995-2015 and currently exceeds total red meat consumption by 46% (primarily a price-driven phenomenon). Similarly, broiler production increased by 280%, and is dominated by a few vertically integrated companies, distributing through large supermarket and quick-service restaurant chains. With recent deregulation of international trade, imports now account for 25-30% of the total broiler meat marketed, which challenges local producers.

Early results include the following: Feed crops compete for agricultural land, and yields and prices fluctuate with weather variability. Controlled-environment housing relies on non-renewable energy, whilst water use for house cleaning and meat processing is high. Recently, South Africa experienced the world's largest listeriosis outbreak, linked to processed broiler meat, emphasising the system's food safety risks and surveillance gaps.

Our whole-system approach encourages participation of a broad spectrum of stakeholders, to identify and prioritise key problem areas. Group model-building techniques allows SD model development by key stakeholders, which facilitates identification of leverage points and potential policy scenarios to simulate. This process creates a sense of communal ownership of the model, and encourages ongoing interest from participants to identify system-based solutions.

DEMAND FOR ANIMAL-SOURCE FOODS: PAST TRENDS AND FUTURE DRIVERS

Komarek, A.M., Dunston, S., Sulser, T., Cenacchi, N., Willenbockel, D., Wiebe, K.

International Food Policy Research Institute, Washington DC

This study examines past trends and future projections of human demand for animal-source foods (ASF) at the global, regional, and country scale. Projections focused on the effect of changes in human population, income, and the income elasticities of ASF demand. After examining trends in the historical demand for ASF, we simulated scenarios out to the year 2050 using a global multimarket model that focuses on the agricultural sector. Results suggest that projections of ASF demand are sensitive to changes in human population, income, and the income elasticity of demand, especially in China, India, Brazil, and USA, although assumptions about how these elasticities may change over time are subject to considerable uncertainty. Stylized scenarios for changes in the income elasticity of demand for red meat in China and India highlight the sensitivity of red meat demand to changes in consumer behaviour. Projections suggest that the growth in ASF demand is expected to be fastest in Africa, although the majority of future ASF demand is expected to come from Asia, especially China and India. Continued improvement in data and analytical methods will be critical for improved understanding of ASF demand and its implications for human health, environmental sustainability, and employment in agriculture.

THE POTENTIAL OF CELLULAR AGRICULTURE TO REDUCE ENVIRONMENTAL IMPACTS OF FOOD SYSTEMS

Tuomisto, H.L., Ernst, E., Järviö, N., Maljanen, N-L., Mazac, R., Moritz, J., Rätty, N., Rynnänen, T.

Future Sustainable Food Systems -research group, University of Helsinki

Food systems, especially livestock production, have a major contribution to environmental change. The possibilities to reduce the environmental impacts of conventional livestock production are limited, and therefore, more radical changes in the food production technologies are required. Cellular agriculture means the use of cell-culturing technologies for producing substitutes for livestock products. The products of cellular agriculture are grouped as cellular and acellular products. Cellular products consists of the actual cells that are cultured, for example, cultured meat that is produced by growing mammalian cells in a bioreactor. Acellular products are substances that are synthesised by the cultured cells, e.g. milk proteins or egg albumin synthesised by microbes (e.g. yeast or micro fungi).

This talk presents the current state of research on the possibilities of products from cellular agriculture to reduce the environmental impacts of livestock production. A few studies have used life cycle assessment for estimating the environmental impacts of cultured meat production in large-scale bioreactors. The results of those studies vary depending on the system design and methodological choices. As the development of cultured meat is still at the laboratory scale and it is not possible to collect data from large-scale production systems directly, the environmental impact estimates rely on many assumptions. It is also unlikely that cultured meat production technology could replace sufficient proportion of meat markets in the short term. However, cellular agricultural technologies that use microbes for producing proteins can be scaled up sooner, and have potential

to reduce environmental impacts, especially when low-emission energy sources are utilized in the production processes. The magnitude of the environmental benefits that could be achieved with these technologies depend on the level of consumers' acceptance and innovation capacity of food industries to produce new interesting products from the novel ingredients.

THE EFFECT OF UPLAND PASTURE MANAGEMENT ON CATTLE PRODUCTION

Williams, N.G., Williams, A.P., Gibbons, J.M., Chadwick, D.R.

SENRGY, Bangor University

A large proportion of the United Kingdom's agricultural land is classified as uplands. The majority of this land is used for livestock production but pasture productivity is often low. This, together with market forces, mean that cattle numbers in the uplands are declining. A continuation of this trend could compromise beef production and lead to other undesirable impacts such as the spread of invasive species. However, improving pasture productivity and grass utilisation could provide numerous benefits such as increasing the length of the grazing season, thereby reducing supplementary feed requirements and decreasing greenhouse gas emissions from agriculture. While many studies have evaluated the effectiveness of pasture improvement methods on increasing pasture productivity, few have focused on the economic and environmental outcomes in relation to the uplands.

Field trials were set up on a typical upland system in North Wales in order to investigate a) the economic and environmental cost-benefits of increasing pasture productivity in the uplands, and b) cattle performance on improved and unimproved uplands and the associated trade-offs. The results showed that while land improvements in the form of lime and fertiliser application led to an increase in upland pasture production, there were no significant interactions between pasture improvement and cattle performance. Results collected post abstract submission will enable us to better understand the effect of altering stocking rates and pasture utilisation on cattle performance. The environmental impact, nitrous oxide emissions in particular, associated with the management options will also be assessed. An improved understanding of this is important for identifying opportunities to increase production efficiencies on-farm as well as reduce greenhouse gas emissions from upland cattle systems. The red meat sector is under considerable pressure to reduce its environmental burden. The findings of this work will be of relevance to this challenge.

ROLE OF LIVESTOCK IN LONG-TERM SOIL HEALTH AND AGRICULTURAL PRODUCTIVITY

Takahashi, T., Rubio, V., Mead, A., Cardenas, L.M., Glendining, M.J., Harris, P., Macdonald, A.J., Lee, M.R.F.

Rothamsted Research

With a growing body of research associating livestock farming with global warming and health costs, a drastic shift towards plant-based diets is often suggested as an effective all-round solution. Implicitly, this argument is predicated on the assumption that reallocation of resources currently assigned to animal production systems will automatically result in efficient cultivation of human-edible crops without long-term agronomic implications. Using data from Rothamsted Research's Broadbalk wheat trial (1843–), this study quantified the marginal effect of manure applications on long-term 'soil health' and nutrient use efficiency (NUE), with a higher-level aim of examining the role of livestock in future arable farming.

We developed a novel computational method tailored for long-term data to evaluate agronomic performances of farming systems. Under the proposed framework, a nutrient freshly introduced into the system was decomposed into three possible fates: (1) instantaneously used for today's production (e.g. nitrogen content in grains); (2) reserved within the system for tomorrow's production (e.g. organic nitrogen retained in soil); and (3) lost without being used for production (e.g. nitrous oxide emitted). Long-term performances of systems were then compared between multiple treatments with and without annual applications of animal-originated organic amendments.

The results showed that short-term NUE ('today') was generally higher under inorganic systems than organic systems of comparable nutrient input rates. A closer investigation revealed, however, that such high performances were almost always accompanied by greater losses of nutrients to the environment, resulting in inferior long-term NUE ('today' + 'tomorrow') and intermittent depletion of soil nutrient stock under inorganic systems. This finding is consistent with a separate study from Rothamsted's North Wyke Farm Platform grazing trial, where higher levels of soil organic carbon were associated with greater nutrient retention in soil and more efficient animal growth. Soil microbial process that underpin these results will also be discussed.

SESSION 2

CHAIR: Dr Brian Cook

[Seminar Room A]

1. **EAT-Lancet score and major health outcomes: the EPIC-Oxford study**
Keren Papier et al. (University of Oxford)
2. **Household dairy production and child growth: Evidence from Bangladesh**
Samira Choudhury and Derek Headey (SOAS, University of London)
3. **Replacing meat with alternative plant-based products (RE-MAP): results of a randomised controlled trial of a behavioural intervention to reduce meat consumption**
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Tammy Y.N. Tong et al. (University of Oxford)

EAT-LANCET SCORE AND MAJOR HEALTH OUTCOMES: THE EPIC-OXFORD STUDY

Knuppel, A*, Papier, K*, Key, T.J., Travis, R.C. *Joint first authorship
Nuffield Department of Population Health, University of Oxford

In January 2019, the EAT-Lancet Commission on Food, Planet and Health's report defined a universal reference diet to promote human and environmental health. To evaluate its association with the risk of major health outcomes, we used data from 46 069 participants enrolled throughout the UK in the European Prospective Investigation into Cancer and Nutrition (EPIC)-Oxford.

Method

Using data from food frequency questionnaires collected between 1993-2001, we created an 'EAT-Lancet score' based on the 14 key recommendations. Participants were assigned a point for meeting each of the recommendations, resulting in possible scores from 0-14. We used multivariable-adjusted Cox proportional hazards models to assess associations between fourths of the EAT-Lancet score and risk of hospitalization or death from ischemic heart disease, stroke and diabetes, and total mortality, ascertained through health record linkage.

Results

High adherence to the EAT-Lancet score was associated with lower risks of ischemic heart disease (HR for highest adherence (scores of 12-14) compared to lowest adherence (scores of 4-9) 0.72, 95%-CI 0.63-0.82) and diabetes (HR 0.41, 95%-CI 0.33-0.50) but was not associated with risk of

stroke (HR 1.06, 95%-CI 0.87-1.28) and not clearly associated with total mortality (HR 0.91, 95%-CI 0.83-1.00) in multi-variable adjusted models. No association was explained by one single recommendation, suggesting a cumulative effect.

Conclusion & discussion

In this large prospective cohort of British adults, the EAT-Lancet reference diet shows beneficial associations for ischemic heart disease and diabetes, although no association with stroke and no clear association with mortality. Still, adherence to the EAT-Lancet score might be a marker for healthy lifestyle; therefore residual confounding might operate.

HOUSEHOLD DAIRY PRODUCTION AND CHILD GROWTH: EVIDENCE FROM BANGLADESH

Choudhury, S., Headey, D.
SOAS, University of London

Research from richer countries finds that dairy consumption has strong positive associations with linear growth in children, but surprisingly little evidence exists for developing countries where diets are far less diversified. One exception is a recent economics literature using the notion of incomplete markets to estimate the impacts of cattle ownership on children's milk consumption and growth outcomes in Eastern Africa. In addition to external validity concerns, an obvious internal validity concern is that dairy producers may systematically differ from non-dairy households, particularly in terms of latent wealth or nutritional knowledge. We re-examine these concerns by applying a novel double difference model to data from rural Bangladesh, a country with relatively low levels of milk consumption and high rates of stunting. We exploit the fact that a cow's lactation cycles provide an exogenous source of variation in household milk supply, which allows us to distinguish between a control group of households that do not own cows, a treatment group that own cows that have produced milk, and a placebo group of cow-owning households that have not produced milk in the past 12 months.

We find that household dairy production increases height-for-age Z scores by 0.52 standard deviations in the critical 6–23 month growth window, though in the first year of life we find that household dairy supply is associated with a 21.7 point decline in the rate of breastfeeding. The results therefore suggest that increasing access to dairy products can be extremely beneficial to children's nutrition, but may need to be accompanied by efforts to improve nutritional knowledge and appropriate breastfeeding practices.

REPLACING MEAT WITH ALTERNATIVE PLANT-BASED PRODUCTS (RE-MAP): RESULTS OF A RANDOMISED CONTROLLED TRIAL OF A BEHAVIOURAL INTERVENTION TO REDUCE MEAT

Bianchi, F., Aveyard, P., Stewart, C., Astbury, N.M., Cook, B., Jebb, S.A.

Nuffield Department of Primary Care Health Sciences, University of Oxford

Reducing meat consumption could prevent non-communicable diseases and protect the environment. While preparing vegetarian meals requires new recipes, meat substitutes may offer an easier approach to start reducing meat intake. However, food neophobia can deter their use.

Aim and Methods

To investigate whether receiving an intervention centered on providing free meat substitutes promotes switching from meat to meat substitutes immediately and four weeks after the intervention. 115 healthy adult volunteers who ate meat regularly were recruited through advertisement and individually randomised to the intervention (N=58) or no intervention control condition (N=57). The four-week intervention comprised (i) free plant-based meat substitutes, (ii) information on the benefits of eating less meat, (iii) success stories of people who reduced their meat consumption, and (iv) recipes. The frequency of weekly meat and meat substitutes consumption was measured with a questionnaire at the baseline and at four and eight weeks and analysed using linear regression models adjusting for baseline.

Results

112 participants completed the trial and were included in the analysis. Compared with the no-intervention control, receiving the intervention led to 3.8 fewer weekly meals containing meat at four weeks ($b=-3.8$; 95%CI=-6.4 to -1.2, $p=0.004$), but there was no evidence of this at eight weeks ($b=-1.4$; 95%CI=-4 to 1.2, $p=0.28$). The intervention led to an additional 6.9 weekly meals containing meat substitutes at four weeks ($b=6.9$; 95%CI=5.5 to 8.3, $p<0.001$) and to an additional 3.4 weekly meals containing meat substitutes at eight weeks ($b=3.4$; 95%CI=1.9 to 5, $p<0.001$).

Conclusion

Interventions that expose consumers to trying meat substitutes promote their use and may reduce meat consumption, but it is uncertain whether the effect on meat consumption is durable.

USING LANGUAGE TO INCREASE THE ATTRACTIVENESS OF PLANT-BASED FOODS

Daneva, T., Semyte, G., Papias, E.K.

Institute of Neuroscience and Psychology, University of Glasgow

Consumer food choices are heavily influenced by expectations of taste and enjoyment. Plant-based foods, however, are typically anticipated to be less enjoyable than meat-based foods, especially among frequent meat eaters. To address this problem and facilitate sustainable consumer choices, we examined the potential of using language to increase the attractiveness of plant-based foods.

In Study 1, we examined the language used in the labels and descriptions of 240 meat-based, vegetarian and vegan ready meals commercially available in the UK. We found that meat-based foods were more often described with words related to sensory experiences of consuming the food, whereas the vegetarian and vegan foods were more often described in terms of ingredients. Based

on the grounded cognition theory of desire (Papies & Barsalou, 2015), we argue that sensory features in food descriptions can induce simulations of eating the food, which can increase a food's attractiveness. Therefore, in Study 2, we manipulated the labels of 40 meat-based and 40 plant-based foods to either contain features that can induce eating simulations, or not. Specifically, we modified the labels to include sensory, hedonic, and eating context features; or only food ingredients and visual features ("Burger patty with rice based on soya protein, cabbage, and beetroot pieces" vs. "Pub-favourite burger with soft soy, crispy cabbage, aromatic rice, and deliciously sweet beetroot"). 174 participants indicated for each food how attractive they found it, and whether the description made them think about what the food would taste and feel like (i.e., whether it induced consumption simulations). In line with our pre-registered hypotheses, enhanced labels increased consumption simulations and attractiveness, and effects on attractiveness were mediated by consumption simulations. Enhanced labels for plant-based foods were especially effective in influencing frequent meat eaters.

This research suggests that descriptions of plant-based foods can be improved, and that theory-based approaches to food descriptions can help facilitate the transition to a more plant-based diet.

SHIFTING CONSUMER DEMAND FOR PLANT-RICH FOODS: AN INTERVENTION PLAYBOOK FOR THE FOOD SERVICE SECTOR

Attwood, S., Mercer, C., Voorheis, P., Vennard, D.
Better Buying Lab, World Resources Institute

To combat climate change and environmental degradation, a large-scale dietary shift is now needed away from overconsumption of meat, especially from ruminant livestock (beef and lamb), and towards more climate-friendly plant-rich foods. The food service industry is uniquely positioned to accelerate this shift by adopting effective behavior change interventions in their operations to influence customers' food choices when dining out. The World Resources Institute conducted a systematic scoping review and industry consultation to identify a shortlist of 'best bet' behavior change interventions to present as guidance to potential changemakers working in the food service sector. 80 eligible academic publications were subject to full-text review from an original list of 4493 located via database searches. Following data extraction and coding, a total of 57 behavior change interventions were identified from this literature. This long list was subsequently ranked by 69 industry representatives via an online survey, yielding a final short list of 23 interventions judged better than average in terms of perceived effectiveness and feasibility to implement in practice. For both criteria, the highest ranked interventions fell under the category of 'presentation' strategies targeting menu layout and design. Industry representatives judged "Use language on menus to emphasize the positive attributes of plant-rich dishes, like their flavor, origins and look-and-feel" (score 6.31 out of 7) as most effective and "List plant-rich dishes in the main body of a menu, not in a separate 'vegetarian' box or 'specials' section" (score 6.19 out of 7) as most feasible to implement in their own operations. Full results of this research will now be published as peer-reviewed industry guidance.

VEGETARIAN DIETS AND RISKS OF TOTAL AND SITE-SPECIFIC FRACTURES: RESULTS FROM THE PROSPECTIVE EPIC-OXFORD STUDY

Tong, T.Y.N., Appleby, P.N., Perez-Cornago, A., Key, T.J
Nuffield Department of Population Health, University of Oxford

There is limited prospective evidence on possible differences in fracture risks between meat-eaters and vegetarians.

Methods

In EPIC-Oxford, dietary information was collected at baseline (1993-2001) and at follow-up (≈2010). Participants were categorised into five diet groups (≈20,106 regular meat-eaters: ≥50g of meat per day, ≈9,274 low meat-eaters: <50g of meat per day, ≈8,037 fish-eaters, ≈15,499 vegetarians and ≈1,982 vegans, with minor variations in numbers for each outcome after pre-specified exclusions) at both time points. Using multivariable Cox regression, we estimated the risks of total (n=3,941) and site-specific fractures (arm, n=566; wrist, n=889; hip, n=945; leg, n=366; ankle, n=520; other main sites i.e. clavicle, rib and vertebra, n=467) by diet group over 17.7 years of follow-up, with outcomes identified through record linkage.

Results

Compared with regular meat-eaters, vegetarians had marginally higher risks of total fractures (hazard ratios and 95% confidence intervals: 1.10; 1.00-1.20) and arm fractures (1.28; 1.01-1.63), while vegans had significantly higher risks of total fractures (1.44; 1.21-1.72) and leg fractures (2.06; 1.22-3.47), and marginally higher risks of arm fractures (1.60, 1.01-2.54). For hip fractures, the risks were higher in fish-eaters (1.28; 1.03-1.59), vegetarians (1.27; 1.05-1.55) and vegans (2.35; 1.67-3.30, p-heterogeneity<0.0001) than regular meat-eaters. There were no significant differences in risks of wrist, ankle or other main site fractures by diet groups. Overall, the significant associations appeared stronger without adjustment for body mass index (e.g. 1.52; 1.27-1.81 in vegans for total fractures), and were slightly attenuated with additional adjustment for total protein (1.41; 1.17-1.69) or dietary calcium (1.32; 1.10-1.59).

Conclusions

Overall, non-meat eaters, especially vegans, had higher risks of either total or some site-specific fractures, particularly hip fractures, which may be partially related to lower body mass index or lower dietary intakes of protein and calcium in these diet groups.

SESSION 3

CHAIR: Dr Alexandra Sexton

[Nelson Mandela Lecture Theatre]

1. **Consumer Acceptance of Cultured Meat: A Systematic Review**
Christopher Bryant and Julie Barnett (University of Bath)
2. **In Search of a Structure to Come: A Meaning System of Cultured Meat in Finland?**
Toni Ryyänen and Anni Toivanen (University of Helsinki)
3. **'Promising the earth': the coverage of cultured meat in the US and UK elite media, 2013-18**
James Painter et al. (University of Oxford)
4. **How not to: reduce food disgust**
Maya Gumussoy et al. (University of Bristol)
5. **What's the beef?: the problematisation of meat eating and sustainable diets**
Damian Maye et al. (University of Gloucestershire)
6. **Multiple health and environmental impacts of foods**
Michael Clark et al. (University of Oxford)

CONSUMER ACCEPTANCE OF CULTURED MEAT: A SYSTEMATIC REVIEW

Bryant, C., Barnett, J.

Department of Psychology, University of Bath

Cultured meat grown in vitro from animal cells may become available to consumers within a few years. This new technology has the potential to realise many benefits relative to conventional meat production, including in sustainability, animal welfare, and public health. However, concerns have been raised about whether cultured meat will appeal to consumers. We present a review of the empirical evidence on consumer acceptance of cultured meat. We find that, while rates of acceptance vary across surveys, some demographics including men, younger people, and politically more liberal people, are more open to cultured meat. We find that most consumers recognise animal welfare benefits, and many recognise environmental benefits, whereas relatively few perceive personal benefits. Food safety appeared to be the most prominent concern, and is likely linked to perceived unnaturalness. Consumers also express doubts about the taste, texture, and price of cultured meat. Quantitative research has demonstrated that measures of acceptance are sensitive to positive and negative information provision, different descriptions and framings of cultured meat, different names for cultured meat, the perceived popularity of cultured meat amongst others, and personal familiarity with cultured meat. Further research has explored consumer opinions of cultured meat across different countries, finding that acceptance seems to be higher in Asia than the United States, and higher in the United States than Europe. We synthesize this research to present a view of how different consumers conceptualise cultured meat, what issues they are concerned about, what benefits they value, and how their views are shaped by different presentations of the technology.

IN SEARCH OF A STRUCTURE TO COME: A MEANING SYSTEM OF CULTURED MEAT IN FINLAND?

Ryynänen, T., and Toivanen, A.

Ruralia Institute, University of Helsinki

The concept of “post farmed animal bioeconomy” describes novel activity in the food sector where the conventional animal products and their production methods are replaced with the alternatives. Cellular agriculture or technologies using cell cultivation to produce agricultural products such as cultured meat, is an example of this novel bioeconomy in action. However, cultured meat is not available on the marketplace and consumers have not tried it yet. Meanwhile, the media presents increasingly novel foods and the related technologies to consumers leaving them wondering about product attributes, new technologies and the science contextualising these innovations. Although the media publicity of and consumers’ perceptions about cultured meat is already studied, people’s reactions to cultured meat are still rather unknown. Our paper presents an on-going research: the purpose is to examine the currently developing meaning system of cultured meat and to identify the themes the people tend to attach to cultured meat. The data consists of 743 naturally occurring comments (i.e. not influenced by the researchers) about cultured meat from the Finnish news audiences. The second author collected the material from the web and the related social media sites including a news article (N=11, 2013-2019) about cultured meat and a free text box for the readers to leave their comments. The developing meaning system of cultured meat will be analysed later in detail. However, the preliminary classification of the topics and the key themes revealed that the tone of people’s opinions ranged from anticipatory positive to fearfully pessimistic. Examples of positive themes include increased animal well-being, human health, sustainable production and full utilisation of novel technologies whereas negative comments revolved around the quality or originality of the product, distrust towards technically tuned foods and overall justification for producing something inferior to the conventional meat or unsustainable compared with vegan alternatives.

The research is part of a project “Cultured meat in post-animal bioeconomy - changing relationships between humans and farmed animals” funded by the Kone Foundation 2019-2022 (grant no: 201802185).

‘PROMISING THE EARTH’: THE COVERAGE OF CULTURED MEAT IN THE US AND UK ELITE MEDIA, 2013-18

Painter, J., and Brennen, S.,

Oxford Internet Institute and Reuters Institute, University of Oxford

‘Cell-based’, ‘cultured’ or lab-grown’ meat has attracted a considerable amount of interest in recent years as an early-stage technology. While scholars are mapping new investment in the field, an updated analysis of the media coverage since 2013 is missing.

Despite uncertainty surrounding the future benefits, risks, and downsides of cell-based meat, news media may already be playing a key role in contributing to the (over-) promissory discourses around it, stressing the potential benefits to the environment, health, animal welfare and feeding a growing

population. In particular, we assess the critique made by Stephens et al. (2018, p 161)* that the abundance of ‘aspiration rhetoric’ surrounding cell-based meat is ‘fueled largely by corporate and media actors’, which ‘has made for <...> an at times prematurely optimistic discourse’.

To test the robustness of this observation, we ask the following research questions:

1. Who or what are the most common news pegs for prompting the mainstream media to cover cultured meat issues?
2. Who is being given space by the media to discuss cultured meat?
3. What are the most common promissory and cautionary narratives used to shape the discussion?
4. To what extent do the news articles show positive, neutral/balanced, or negative sentiments towards cultured meat?

In order to seek answers to these questions, detailed content analysis was conducted on 244 articles from the print and online versions of 12 US and UK legacy media outlets from 1 January 2013 (to include the year when the first lab-grown burger was launched) to the end of March 2019. Early results suggest that much of the coverage is indeed prompted by the industry, and key voices are often marginalised. The media treatment of cell-based meat is overwhelmingly positive.

* Stephens, N., et al. (2018). Bringing cultured meat to market: Technical, socio-political, and regulatory challenges in Cellular Agriculture. *Trends in Food Science & Technology*, 78, 155 -166

HOW NOT TO: REDUCE FOOD DISGUST

Gumussoy, M.R., Hunt, D.F., Rogers, P.J.

School of Psychological Science, University of Bristol

Insects are a more sustainable and nutritious alternative to conventional livestock. However, consuming them is perceived as disgusting among the Western population. This study investigated the effectiveness of educational information to reduce disgust towards eating insects. Participants (n = 104) attended the lab for two test sessions on separate days. In the first session their ad libitum intake of falafels was measured in order to control for individual differences in meal size. In the second session they were asked to evaluate, and eat, different falafels which some were led to believe contained mealworm flour.

There were four conditions, which differed according to information provided in a short passage:

- 1) Control – participants informed falafels contain chickpeas.
- 2) Mealworm – participants informed falafels contain mealworm flour.
- 3) Mealworm + education – participants informed falafels contain mealworm flour and various nutritional and environmental benefits of entomophagy were summarised.
- 4) Threat – participants informed falafels contain chickpeas and that the experiment would include an experience of mild pain (to control for general negative arousal).

Importantly, the falafels were the same for all participants and did not contain mealworm flour. Disgust was measured using: tactile sensitivity, liking for and desire to eat the falafels, latency to eat and amount of falafel consumed. Contrary to prediction, participants in the Mealworm + education condition showed significantly greater disgust (lower liking, desire to eat and intake) than those in

the Control condition, whereas these measures did not differ significantly between the Control and Mealworm conditions. These findings could be attributed to the Mealworm passage normalising the cooking of mealworms thus transforming them into ‘food’, while the rational arguments included in the Mealworm + education passage were insufficient to reduce the deep-rooted, irrational, disgust response. These results suggest that using rational educational arguments to reduce food disgust towards entomophagy is relatively ineffective.

WHAT’S THE BEEF?: THE PROBLEMATISATION OF MEAT EATING AND SUSTAINABLE DIETS

Maye, D¹., Urquhart, J¹., Fellenor, J²., Barnett, J²., Potter, C³., Luna, A³

¹ *Countryside and Community Research Institute, University of Gloucestershire, UK*

² *University of Bath, UK*

³ *Imperial College London, UK*

This paper examines the recent debate about meat eating and sustainable diets. More specifically, we consider meat eating as a ‘hot topic’ debated in public discourse in response to the publication of the EAT-Lancet Commission (2019) ‘Food in the Anthropocene’ report. This report called for a radical shift and reduction in the amount of meat, particularly red meat, we consume as a society to reverse negative food system impacts on the planet. The report sparked significant public debate. Using Twitter data and analysis of newspaper articles, we analyse the report and the response its recommendations generated. As well as examining this specific moment of meat eating problematisation, we consider also strategies of responsabilisation proposed to address the problem, including counter-strategies that contest the science behind the publication, differentiating, for example, between different systems of meat production or challenging the nutritional logic of reduced meat diets.

The ‘sustainable diets’ concept (Mason and Lang, 2017) raises important questions regarding the ethics of food production consumption, including entanglements with humans and nonhumans and the social and political implications of transitioning to food choices where we eat less meat and more plant-based alternatives. The case study raises wider questions about planetary boundaries and ethics and accountability in agri-food governance. This includes consideration of the way food politics is evolving in the public sphere, particularly the role of social media as an arena of interaction that generates debate and in some cases leads to direct confrontation between ethical values, social norms and sustainability choices.

MULTIPLE HEALTH AND ENVIRONMENTAL IMPACTS OF FOODS

Clark, M.A.^{1,2}, Springmann, M.¹, Hill, J.², Tillman, D.³.

¹ *University of Oxford*

² *University of Minnesota*

³ *School of Environmental Science and Management, University of California*

Food choices are shifting globally in ways that are negatively affecting both human health and the environment. Here we consider how consuming an additional serving per day of each of 15 foods is associated with 5 health outcomes in adults and 5 aspects of agriculturally driven environmental degradation. We find that while there is substantial variation in the health outcomes of different foods, foods associated with a larger reduction in disease risk for one health outcome are often associated with larger reductions in disease risk for other health outcomes. Likewise, foods with lower impacts on one metric of environmental harm tend to have lower impacts on others. Additionally, of the foods associated with improved health (whole grain cereals, fruits, vegetables, legumes, nuts, olive oil, and fish), all except fish have among the lowest environmental impacts, and fish has markedly lower impacts than red meats and processed meats. Foods associated with the largest negative environmental impacts—unprocessed and processed red meat—are consistently associated with the largest increases in disease risk. Thus, dietary transitions toward greater consumption of healthier foods would generally improve environmental sustainability, although processed foods high in sugars harm health but can have relatively low environmental impacts. These findings could help consumers, policy makers, and food companies to better understand the multiple health and environmental implications of food choices.

SESSION 4

CHAIR: Dr Christina Potter

[Seminar Room A]

1. **Appraising the socio-ecological role of pasture-fed beef - as part of the UK food system and in the context of a warming planet**
Claire Waterton and Dr Lisa Norton (Lancaster University)
2. **Food system “tracers” to analyse healthy and sustainable food systems: tracing milk in India**
Kerry Ann Brown et al. (LSHTM, University of London)
3. **Environmental effects of livestock production in Europe – exploring regional differences**
Marja Roitto et al. (University of Helsinki)
4. **Sustainability of dairy specialization in Ireland depends on land use consequences and diet change context**
Rémi Prudhomme et al. (National University of Ireland)
5. **How Bad Is It? A Systematic Review of the Sustainability of Beef Production in Seven Leading European Countries**
Lana Repar et al. (University College Cork)
6. **The greenhouse gas impacts of converting livestock farming in England and Wales to organic methods**
Laurence Smith et al. (Cranfield University and Royal Agricultural University)

APPRAISING THE SOCIO-ECOLOGICAL ROLE OF PASTURE-FED BEEF - AS PART OF THE UK FOOD SYSTEM AND IN THE CONTEXT OF A WARMING PLANET

Waterton, C., and Norton, L.
Lancaster University

In this paper we outline the socio-ecological methods and preliminary findings of the UK GFS programme’s “SEEGSLIP” project (“Sustainable and Ecological Grazing Systems – Learning From Innovative Practitioners”). The research (2018 - 2021) aims to understand and evaluate the methods of farmers who have changed their production systems in order to produce beef on a 100% grass/pasture diet (no grain or other feed in the diet). The certification body for this kind of production – Pasture for Life Association (PfLA) – supports farmers producing in this way and claims multiple benefits of a 100% grass/pasture diet in ruminants, including: improved soil fertility, carbon capture, increased flood and drought resilience, efficient land use, decrease in fossil fuel use, support of biodiversity, animal welfare and benefits to human health. Our preliminary ecological and sociological field results from PfLA certified farms across the UK will be explored in this presentation with reflections on each of the above issues. The paper will consider the way in which the farmers’ innovations in pasture and cattle management usher in a substantially altered set of relationships on the farm, involving changes in landscape, ecology, and the social, technical and capital supports within the system. At a time when eating red meat is high on the public agenda regarding health and environmental issues, we aim to open up for discussion the potential role for pasture-fed beef as a way of addressing planetary warming, biodiversity loss and ethical/healthy meat consumption.

FOOD SYSTEM “TRACERS” TO ANALYSE HEALTHY AND SUSTAINABLE FOOD SYSTEMS: TRACING MILK IN INDIA

Brown, K.A¹., Knai, C¹., Srinivasapura Venkateshmurthy, N^{2,3}., Mohan, S^{2,3} on behalf of the SHEFS consortium

¹ Faculty of Public Health & Policy, London School of Hygiene & Tropical Medicine

² Centre for Chronic Disease Control, New Delhi, India

³ Public Health Foundation of India, Gurgaon, India

A challenge for Indian policy makers is to minimise the environmental footprint of milk consumption and production, whilst protecting public health and social welfare. The aim of this work is to trace the ‘journey’ of milk through the Indian food system to help inform policy implementation/options that can enable a healthier and more environmentally sustainable and equitable food system.

A case study design and multiple data collection methods are used to analyse the food system from diverse perspectives. These methods included a scoping [grey/white] literature review of milk policies and value chain analyses; qualitative semi-structured interviews with key actors; and community engagement via photovoice participatory action research. Data are combined using thematic analysis and a coding template based on three a priori areas: i) current policy context; ii) current policy coherence & alignment across health, environment, equity objectives; iii) future policy opportunities.

Preliminary results support the complex challenges and opportunities that arise from India being the largest producer of milk in the world. Public health policies such as food-based dietary guidelines encourage domestic milk consumption as an efficient means of achieving sufficient population calcium intake, especially in childhood and adolescence. Agricultural policies support dairy production and the associated beneficial employment and income generating opportunities, particularly for marginal and women farmers. There is a growing concern, however, as to how the dairy industry can negate negative environmental impacts, such as chemical pollution (antibiotic, pesticide, fertiliser use), risks to bio-/genetic-diversity, overuse of resources (water) and GHG/carbon emissions.

Further analysis will inform transformative labs, system dynamics modelling and multi-criteria mapping analysis, where key actors will identify feasible opportunities for aligning policy goals, such as considering how changes in milk production and consumption can inform sustainable food-based dietary guidelines or help to achieve multiple state/national/international Sustainable Development Goals.

ENVIRONMENTAL EFFECTS OF LIVESTOCK PRODUCTION IN EUROPE – EXPLORING REGIONAL DIFFERENCES

Roitto, M^{1.}, Heusala, H^{2.}, Kuosmanen, N^{2.}, Autio, S^{2.}, Rinne, M^{2.} and Tuomisto, H¹

¹ *University of Helsinki, Finland*

² *Luke Natural Resources Institute Finland*

Environmental impact of livestock production varies across different regions in Europe due diverse agricultural management practices and livestock production systems. The specialization and intensification of European farming systems during last decades has increased productivity but also led to increased pressure on the environment. The combination of high productivity, efficient land use, low greenhouse gas emissions and low pressure on local environment seems to be difficult to meet. Netherlands has efficient production per unit of agricultural land, but environmental pressure such as ammonia emissions, nutrient surpluses and use of pesticides are also high per unit of land. Various methods have been developed for evaluation and quantification of environmental effects of livestock production, such as agri-environmental indicators and life cycle assessment that is used to quantitatively model environmental effects of products over all stages of its life cycle. Comparison and ranking of the systems or countries depend on selected impact category and which functional unit is used. Special attention has been paid on the greenhouse gas emissions of livestock sector, whereas, for example, biodiversity, soil carbon sequestering, land use and land use change and ecotoxicity are less studied.

The aims of this study is to compare environmental effects of livestock production in selected European countries that differ in number, density and distribution of the livestock species. In addition, we evaluate differences between production systems. We pool environmental and production data and use two different frameworks for evaluating environmental impact of the agriculture and more specifically livestock production 1. Driving forces–Pressures–State–Impact–Responses framework (agri-environmental indicators) and 2. Life cycle assessment analyses. We use principal component analysis to identify the main factors of pressure caused by livestock production and test two clustering methods (K means and fuzzy C means) for grouping the regions. The initial results will be discussed in this talk.

SUSTAINABILITY OF DAIRY SPECIALIZATION IN IRELAND DEPENDS ON LAND USE CONSEQUENCES AND DIET CHANGE CONTEXT

Prudhomme, R^{1.}, Styles, D^{2.}, Ryan, M^{3.}, O'Donoghue, C¹

¹ *National University of Ireland, Galway, Co. Galway, Ireland*

² *School of Environment, Natural Resources and Geography, Bangor, Gwynedd LL57 2UW, UK*

³ *Teagasc Rural Economy and Development Programme, Mellow Campus, Athenry, Co. Galway, Ireland*

The Food Wise 2025 seeks to double the value of Ireland's agri-food exports between 2014 and 2025, with a focus on the dairy sector. Meanwhile, Ireland faces a major challenge to meet international commitments on climate change, and has set an ambitious target of "carbon neutrality" in the agriculture, forestry and other land use (AFOLU) sector. The SeQUESTER project is exploring pathways to reach sustainable "carbon neutrality" by 2050. One of these pathways involves the specialisation of livestock towards dairy production, minimizing beef production. This could potentially reduce emissions per calorie produced whilst allowing for alternative land uses

(CCAC 2019), such as afforestation to increase carbon sequestration. However, this specialisation could lead to negative side effects, such as high nutrient surpluses on intensive specialised dairy farms and the possible displacement of beef production to countries with high emissions intensities per kg of beef produced. Currently, the global demand for beef is much higher than the world meat production from dairy cattle, but this could change by 2050 depending on long-term trends in diet and development of 'lab meat'.

In this paper, we explore the national and global environmental trade-offs resulting from the specialisation of Irish livestock production, including: (i) reduced AFOLU emissions; (ii) enhanced carbon sequestration through afforestation on spared land; (iii) increased nutrient surpluses associated with dairy intensification; (iv) international GHG and nutrient "leakage" via international displacement of beef production. We focus on the influence of wider diet and land use contexts on these trade-offs by evaluating environmental outcomes for different specialization scenarios using a consequential life cycle assessment framework (Styles et al. 2015), and including downstream carbon implications of harvested wood products (IPCC 2006) and emissions associated with additional beef production outside Ireland (FAO 2018). The study emphasizes the importance of combining both supply and demand side measures to avoid pollution displacement and/or pollution swapping in livestock climate mitigation strategies.

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HOW BAD IS IT? A SYSTEMATIC REVIEW OF THE SUSTAINABILITY OF BEEF PRODUCTION IN SEVEN LEADING EUROPEAN COUNTRIES

Repar, L., Bogue, J., Hennessy, T., Doran, J

Cork University Business School, University College Cork, Ireland

Agriculture continues to underperform in relation to sustainability goals, despite its key role in global food production, the state of consumers' health and the economy. The latest data show that agriculture contributes to 11% of greenhouse gases and 92% of ammonia emissions in Europe, with the beef sector globally responsible for approximately 105 kg of CO₂eq per 100g of protein. Furthermore, none of the EU countries are likely to achieve their targets for reducing carbon emissions by 2020. France, Germany, United Kingdom, Italy, Ireland, Poland and Spain are the main players in the beef sector and account for 80% of European beef production, therefore developing sustainability policies across these countries needs to account for country and sector dependent characteristics.

The aim of this study was to determine the sustainability levels of beef production in the leading countries to allow for a macro view of sustainability across the European beef sector. A systematic review, using a PRISMA protocol, was undertaken to examine studies reporting results of the environmental, economic and social impact of beef production in the leading European countries

across three databases between 2017-2019. An initial search recorded 4,179 published works, which was reduced to 34 original studies included in this current study, following the application of specific eligibility criteria. The aggregated data showed that sustainability levels in the leading European countries were moderate across the triple bottom line. The United Kingdom showed the most consistent sustainability levels in beef production, while France had the lowest levels. This study concludes that the European beef sector requires more efficient measures for achieving sustainability at both an individual country level and at a European level. This is especially important for current and future European trade deals and market opportunities, since consumer insight trends reveal a strong demand for more sustainable production practices.

THE GREENHOUSE GAS IMPACTS OF CONVERTING LIVESTOCK FARMING IN ENGLAND AND WALES TO ORGANIC METHODS

Smith, L.G.^{1,2}, Kirk, G.J.D¹., Jones, P.J³., Williams, A.G¹

¹ *School of Water, Energy & Environment, Cranfield University, UK*

² *School of Agriculture, Food and Environment, Royal Agricultural University, UK*

³ *School of Agriculture, Policy and Development, University of Reading, UK*

Livestock farming is particularly implicated within UK Government commitments to net-zero greenhouse gas (GHG) emissions. Commentators have therefore called for a shift to lower-meat diets and there has been a growing interest in the GHG mitigation potential of low-input livestock systems such as organic farming. We therefore assessed the extent to which a 100% shift to organic farming could contribute to GHG reduction in England and Wales, using linear programming and Life Cycle Assessment.

Overall livestock product outputs fell sharply compared to a non-organic baseline. Beef and sheep production increased, potentially leading to a conflict with national dietary recommendations, while monogastric outputs fell sharply. Direct GHG emissions from livestock were reduced under organic farming, but when the increased overseas land use required to compensate for shortfalls in domestic supply was factored in, net emissions were greater. Enhanced soil carbon sequestration could offset only a small part of the higher overseas emissions under most scenarios.

There are undoubted local environmental benefits to organic livestock farming, however these benefits need to be set against the requirement for an expansion in agricultural production areas. As well as increased GHG emissions from compensatory changes in land use, there are substantial opportunity costs from reduced availability of land for other purposes, such as greater C storage under woodland. A widespread conversion to organic farming is therefore infeasible without substantial changes to national diets and/or organic farming systems, if net-zero is to be achieved.

POSTER ABSTRACTS

1	Kate Bamford et al.	The role of acute and chronic mastitis in shaping the microbial communities extracted from sheep milk
2	Elisa Becker & Natalia Lawrence	The Role of Meat Disgust in Meat-free Diets
3	Roberta Alessandrini et al.	Food Futures: Narratives of Food Systems for Diet and Nutrition along the Shared Socioeconomic Pathways (diet-SSPs)
4	Tommy Boland et al.	Multispecies swards deliver multiple benefits in pasture-based systems
5	Charlotte-Anne Chivers et al.	Reducing the impacts of diffuse water pollution from livestock farming through improved dissemination of scientific evidence
6	Amy Coombs	Pre-carbon Agriculture for a Post-carbon future: Brassica napus for convertible husbandry in England and Scotland from 1715 to 1830
7	Brian Cook et al.	Evaluating the effect on sales of moving meat-free products to the meat aisle in a supermarket: A pilot non-randomised before and after study
8	Alice Evatt	Agribusiness & The Climate Emergency: Why Aren't We Talking About Agricultural Responsibility?
9	Angelina Frankowska et al.	How Do UK Cooking Methods Contribute to Climate Change?
10	Josefa Garzillo et al.	Meats and ultra-processed foods in the Brazilians' diet: potential to reduce carbon footprint and water footprint by adapting the effective food consumption with cancer prevention recommendations
11	Helen Harwatt and Matthew N Hayek	Eating away at climate change with negative emissions: Repurposing UK agricultural land to meet climate goals
12	Cansu Kandemir et al.	Household food waste simulation model: investigation of innovations to reduce meat and dairy food waste
13	Laura Kehoe et al.	Improving incentives for farmers to protect native vegetation in Mato Grosso, Brazil
14	Jean Kennedy et al.	A study protocol: The HeartLand Project: Health, Environment, Agriculture, Rural development: Training network for LAND management
15	Anika Knuppel et al.	Meat intake and cancer risk: prospective analyses in UK Biobank
16	Alana Marielle R G Kluczkovski	Childhood obesity and climate change in the UK - the contribution of animal and non-animal protein sources
17	Natalia Lawrence	Giving pork the chop: Response inhibition training to reduce meat intake. Natalia Lawrence and Bethany Camp
18	Kate Lewis & Laura Green	Looking after lambs: identifying the optimum typology for treatment of footrot
19	Graham Mcauliffe et al.	Demystifying the unit dependency of LCA metrics through better understanding of human nutrition

20	Evelyn Medawar	Unconventional eating behaviour and its effect on brain circuits and on gut-brain-communication
21	Camilla Almeida Menezes & Leticia Baird	Implementation of sustainable school feeding in Bahia state, Brazil, as a strategy for efficient use of public resources
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31	Ishwar Pun et al.	Soil quality changes in a rotation with outdoor pigs and annual crops
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33	Julie A. Schmidt et al.	NMR metabolic profile in male meat-eaters, fish-eaters, vegetarians and vegans in EPIC-Oxford
34	Helen Sheridan et al.	UCD Lyons Farm Long-Term Grassland Experiment
35	Tammy Tong et al.	The associations of major foods and fibre with risk of ischaemic and haemorrhagic stroke: a prospective study of 418,329 participants in the EPIC cohort
35	Yeliz Vural et al.	Consumer attitudes towards alternative meat products: expectations about taste and the role of disgust
37	Jessica Witt	Assessment of spatial, environmental, and management effects on lameness prevalence in UK sheep flocks
38	Monika Zurek et al.	Assessing the EU food system and innovation options for the livestock sector - The SUSFANS Project and Its Findings

[1] THE ROLE OF ACUTE AND CHRONIC MASTITIS IN SHAPING THE MICROBIAL COMMUNITIES EXTRACTED FROM SHEEP MILK

Kate Bamford¹, Kevin Purdy¹, Andrew Bradley^{2,3}, Laura Green⁴

¹ *School of Life Sciences, University of Warwick*

² *Quality Milk Management Services, Wells*

³ *School of Veterinary Medicine and Science, University of Nottingham*

⁴ *College of Life and Environmental Sciences, University of Birmingham*

Mastitis is endemic in suckler sheep flocks in the UK and has major implications for farm sustainability and sheep health and welfare. Little is known about the dynamics of the disease within the flock, and this study aims to investigate the role of pathogen transmission and persistence in the individual and within a flock.

Milk samples were collected during a two-year longitudinal study and cultured aerobically. Each morphologically distinct isolate was given a species identification and a distinct mass spectrum where possible using MALDI-ToF. Mass spectra were clustered based on similarity and replicates used to determine a threshold Euclidian distance; clusters under this were considered to be the same bacterial strain.

Staphylococcus was the most common genera isolated, found in 46.4% of milk samples, followed by Enterococcus (17.8%) and Bacillus (14%). Persistence of strains - where the same strain was identified within the same ewe – was seen in 19 (6.6%) strains. 166 (58%) strains were identified in more than one ewe within the same flock and defined as potential transmission. Sheep with signs of clinical disease had a significantly smaller diversity of strains when disease was present ($p < 0.05$).

Isolates were successfully strain-typed, allowing analysis of potential transmission and persistence events. Multiple strains were seen more than once within flocks, indicating that some mastitis-associated pathogens are potentially contagious or transmitted from the shared environment. Lower bacterial diversity in diseased animals suggests that mastitis is caused by overgrowth of a single opportunistic pathogen.

[2] THE ROLE OF MEAT DISGUST IN MEAT-FREE DIETS

Elisa Becker, Prof Natalia Lawrence

University of Exeter

The impact that meat consumption has on the environment is becoming a concern to an increasing number of consumers. For some, reducing meat intake takes a lot of self-control. However, some people report to be disgusted by meat and therefore find it easy to follow a meat-free diet. This suggests that meat disgust might moderate the relationship between self-control and keeping up a vegetarian diet.

To explore this phenomenon further, an online survey is currently being conducted. Participants are being recruited from several channels, including a student sample and members of a community research database with a target sample size of $n = 1040$ that aims to represent various demographic sections and people with different diets and meat consumption levels. We ask two main research questions: 1) Does disgust moderate the relationship between self-control and low meat

consumption in those who are trying to limit their meat intake? 2) Is meat disgust an explicit concept only or do implicit associations between meat and disgust match self-reported disgust?

Meat disgust is measured explicitly by self-report and implicitly by an Implicit Association Test (IAT). Further measures include meat consumption at baseline and at six-month's follow-up, trait self-control, general disgust sensitivity and personal reasons for reducing meat intake. The role of meat disgust in the relationship between self-control and meat consumption will be tested in a moderation analysis.

We will present the results of our analysis of the role of meat disgust in the relationship between self-control and meat consumption. We will also discuss the correlation between implicit and explicit meat disgust and how these are associated with diet and other factors. Understanding how meat disgust helps some people maintain a vegetarian diet may help us develop interventions targeted at meat consumption in the future.

[3] FOOD FUTURES: NARRATIVES OF FOOD SYSTEMS FOR DIET AND NUTRITION ALONG THE SHARED SOCIOECONOMIC PATHWAYS (DIET-SSPS)

Benjamin Leon Bodirsky, Roberta Alessandrini, Hermine Mitter, Katja-Maria Prexl, Adrian Leip, Prajal Pradhan, Antje Gonera, Anna Birgitte Milford, Alberto Sanz Cobeña, Isabelle Weindl, Hermann Lotze-Campen, Alexander Popp

Wolfson Institute of Preventive Medicine, Queen Mary University of London

Diet shapes human health and has been a major driving force of global change during the 21st century. The establishment of narratives encompassing patterns of dietary change is therefore crucial for exploring visions of future development, harmonising scenario-based assessments within the scientific community, and facilitating communication between scientists, policymakers, and other stakeholders. The Shared Socioeconomic Pathways (SSPs) have recently been established as a focal point of scenario analysis. However, they remain vague with respect to food systems and, in particular, to the development of dietary drivers, patterns, and outcomes.

This article formulates and discusses five plausible dietary narratives compatible with the SSPs, each unique with respect to its main actors, policy framework, food supply chain organisation, consumer context, dietary composition, and health outcomes in cases of under- and over-nutrition. This approach allows for a more comprehensive study of food system dynamics than is possible via quantitative approaches and enables researchers to investigate more explorative futures compared to model-derived scenarios.

[4] MULTISPECIES SWARDS DELIVER MULTIPLE BENEFITS IN PASTURE-BASED SYSTEMS

T.M. Boland¹, C. Grace², M.B. Lynch¹, P. Murphy¹, O. Schmidt¹, S. Lott¹, E. Brennan¹, S. Higgins³, R. Fritch⁴, H. Sheridan¹.

¹*School of Agriculture and Food Science Centre, University College Dublin*, ²*Devenish Nutrition, Dowth, Co. Meath, Ireland*, ³*Agri-Food and Bioscience Institute, Belfast*, ⁴*Science Foundation Ireland, Thre Park Place, Upper Hatch St, Dublin 2, Ireland*.

In 2013 two experiments were established to determine the potential of multispecies swards (MSS) to support pasture-based livestock production systems. The first experiment was a simplex-centroid designed experiment used to investigate herbage production and quality of grass, legume and herb mixtures at varying N inputs compared to a PRG sward receiving 250 kg N/ha (PRG250). These plots were also used to determine the impact of sward type on earthworm population and diversity, invertebrate diversity and resistance of swards to weed ingress. The second experiment was a grazing study to compare ewe, lamb and pasture performance from multispecies or PRG swards.

In Experiment 1, at 135 kg N/ha, all legume containing mixtures had higher annual production than the PRG250. At 0 kg N/ha, a sward containing 60 % legume produced 2600 kg DM/ha more herbage than PRG250. All legume containing mixtures had a higher CP content in all seasons (on average 20 % higher) and lower NDF content in autumn compared to grass monocultures (on average 18 % lower). Multispecies swards supported greater earthworm populations and greater above ground invertebrate populations. Additionally MSS were more resistant to weed ingress and the DM yield of MSS were more consistent over the 3 years of the study compared to PRG250. A modelling exercise also identified a 90% reduction in nitrous oxide emissions per kg DM in the MSS compared to PRG250.

In Experiment 2, there was similar herbage production from all sward types despite MSS swards receiving 45% less nitrogen fertiliser. Grazing multispecies swards increased lamb performance in terms of increased weaning weight, reduced days to slaughter and reduced requirement for anthelmintic for animals grazing swards containing grasses, legumes and herbs compared to PRG swards.

In conclusion MSS have the potential to enhance the physical and environmental performance of pasture-based livestock production systems.

The experimental work reported herein was funded by the Department of Agriculture, Food and the Marine's Competitive Funding Programmes (11/S/147).

[5] REDUCING THE IMPACTS OF DIFFUSE WATER POLLUTION FROM LIVESTOCK FARMING THROUGH IMPROVED DISSEMINATION OF SCIENTIFIC EVIDENCE

Charlotte-Anne Chivers, Adie Collins, Michael Winter
University of Exeter and Rothamsted Research

Diffuse water pollution from agriculture remains a major environmental concern and must be a key consideration when debating the sustainability of livestock production in conjunction with the other major environmental challenges we face including climate change, soil health, air pollution, and animal welfare. Livestock has significant impacts on water quality due to various farming practices

including livestock poaching, inappropriate outwintering, leaching of fertilisers, maize cropping on unsuitable land, and unfenced watercourses. Numerous scientific studies have been undertaken to explore the varied impacts of these practices, however, in many cases these findings have not been disseminated appropriately to farmers and other actors; in fact, they are often misconstrued when shared by non-experts. This doctoral research is therefore beginning to explore ways of ensuring that scientific evidence influences farming practices.

An interdisciplinary approach has been utilised consisting of both social science and geophysical methods to discuss how both farmers and advisors would like this information to be provided in future. The example of scientific evidence being used for this study is the sediment fingerprinting approach, whereby complex methods are utilised to apportion sediment, enabling researchers to determine likely sediment sources contributing to diffuse pollution. Despite having numerous impactful publications, the dissemination of sediment fingerprinting within the English advisory system has been impeded due to the difficulties which arise when explaining scientific uncertainty and the complex, varied methodologies to non-scientists. This research is highly relevant to numerous agricultural research projects as it is vital that scientific findings surrounding topics which ultimately affect the general population (including the ongoing debate surrounding meat consumption) are relayed appropriately, coherently and accurately to ensure natural science continues to be seen as credible, relevant and legitimate by non-scientists. It is also important that we continue to engage with non-scientists to ensure they feel empowered and so that we can carry out research which is highly relevant to the needs of our end-users.

[6] PRE-CARBON AGRICULTURE FOR A POST-CARBON FUTURE: BRASSICA NAPUS FOR CONVERTIBLE HUSBANDRY IN ENGLAND AND SCOTLAND FROM 1715 TO 1830

Amy Coombs

The University of Chicago

US Department of Agriculture trials have recently elucidated the biochemical mechanisms by which meals crushed from *B. napus* grown for vegetable oil can replace Chloropicrin and Methyl Bromide for soil pathogen suppression. Historians have largely neglected *B. napus*, but eighteenth century farmers also harnessed the species for oil and to fight pests. Numerous letters of patent, farming journals, agricultural surveys, and planting protocols recommended *B. napus* plantings and green manuring to improve soil quality. I use ArgGIS to map 600 seed mill locations and data mining to process Board of Agriculture General Views and show that the technology was used for soil improvement in nearly every county in England and Scotland by the late nineteenth century.

Archival studies move beyond questions of density of adoption and disbursal to explore evidence that eighteenth century farmers developed sophisticated spatial and temporal design strategies to integrate *Brassica rapa* subsp *rapa*, grown for white turnip roots to feed livestock, and the yellow flowering *B. napus* into convertible husbandry systems to increase herd size and manure inputs for corn. Farmers physically integrated rapeseed into the same field as turnips, used *B. napus* green manures prior to turnip plantings, and also used rapeseed as an alternative fodder. *B. napus* could be fed to animals as green fodder growing in the field, as dry stalk for winter hay, or as crushed cake from the oil mill. From this, I shed new light on the importance of integrated design evolution as a chronological and structural feature of the British Agricultural Revolution.

[7] EVALUATING THE EFFECT ON SALES OF MOVING MEAT-FREE PRODUCTS TO THE MEAT AISLE IN A SUPERMARKET: A PILOT NON-RANDOMISED BEFORE AND AFTER STUDY

Brian Cook, Jennifer Hollowell, Constantinos Koshariis, Christina Potter, Cristina Stewart, Susan Jebb
Nuffield Department of Primary care Health Sciences, University of Oxford

Background: Physical environments within which food choices are made can exert significant influence on food selection and could be used to influence consumer demand for meat.

Supermarkets are a promising setting for such interventions because of their potential to reach a large number of diverse consumers. However, the evidence on the effectiveness of in-store interventions to reduce meat consumption is lacking.

Study aims: The primary aim of this study is to determine whether repositioning meat-free alternatives from the vegetarian section to the meat aisle in a supermarket leads to changes in meat sales. Additionally, it assesses the change in purchases of meat-free alternatives. It will explore the feasibility and practical aspects of delivering and evaluating an in-store intervention in partnership with a commercial retailer, develop and refine methods of analysis, and obtain data needed to design and conduct a larger, more definitive in-store intervention study.

Methods: This is a non-randomised controlled before and after study comparing sales data in 20 supermarket stores delivering the intervention and a matched sample (provisionally 1:5) of control stores. The intervention was implemented by stores in the week beginning 27 January 2019. The set-up period (the first week) will be excluded from the analysis of sales.

The study will compare changes in sales of meat and meat-free alternatives in the intervention and control stores using aggregated store level sales data across two 12-week time periods: a pre-intervention comparison period and the intervention period. Subject to data availability, an interrupted time series analysis will evaluate changes in weekly sales of meat and meat-free alternatives associated with the intervention. Intervention fidelity was monitored through store visits.

Results: This presentation will describe the findings of this pilot evaluation and reflect on practical lessons learned.

[8] AGRIBUSINESS & THE CLIMATE EMERGENCY: WHY AREN'T WE TALKING ABOUT AGRICULTURAL RESPONSIBILITY?

Alice Evatt

Faculty of Philosophy, Balliol College, University of Oxford

Major agribusinesses and major fossil fuel companies contribute significantly to the climate emergency. We hold the fossil fuel industry and large companies like ExxonMobil, BP, Shell and Chevron responsible; we take them to court, we divest, we demand change. Yet, we have more or less left the agricultural industry alone. JBS, Carson and Cargill are not staples of household vocabulary, let alone the climate indictment vocabulary. In some instances, farmers and agriculture are even presented as mere victims of climate change. Why do we treat these industries and companies so differently, given that they both contribute to the same problem in similar ways? Are major agribusinesses and the agricultural industry responsible and blameworthy for climate change

in the same respect? Or, is there perhaps a salient difference between the two industries that would exculpate agriculture from blame and duty? This paper is an attempt to answer these questions.

The agricultural and food sector is vast and complex. I limit my focus here to the meat and dairy industry since these two contribute the highest degree of emissions within the sector. To assess the responsibility of these industries and relevant agribusinesses, I draw on the work of Henry Shue and Frumhoff et. al.. In 2015 and 2017 respectively, these authors examined the responsibilities of carbon producers within the energy sector.⁶ I test the meat and dairy industry against their conclusions, and in particular, against Frumhoff et. al.'s 4-step criterion for carbon producer responsibility. I conclude that there are sufficient reasons and overlaps between the two industries for us to hold the meat and dairy industry and agribusinesses likewise morally responsible for the climate emergency.

[9] HOW DO UK COOKING METHODS CONTRIBUTE TO CLIMATE CHANGE?

A. Frankowska^a, C.L. Reynolds^b, S.L. Bridle^a, F. Rauber^c, R. Levy^d, J. T. da Silva^{d,e}, A. Kluczkowski^a, X. Schmidt Rivera^f

^a School of Physics and Astronomy, University of Manchester, Manchester, United Kingdom

^b Department of Geography, University of Sheffield, Sheffield, United Kingdom

^c Department of Nutrition, School of Public Health, University of São Paulo, São Paulo, Brazil

^d Department of Preventive Medicine, School of Medicine, University of São Paulo, São Paulo, Brazil

^e HCor Research Institute, São Paulo, Brazil

^f Institute of Energy Futures, Brunel University London, London, United Kingdom

Food contributes up to 30% to the global greenhouse gas emissions (GHGe). In the UK, agriculture and farming were the largest contributors (e.g. 56 mt CO₂eq.) in 2013, followed by manufacturing (e.g. 8 mt CO₂eq.) (DERA 2017). Although great efforts have been made towards understanding the impacts of food consumption (e.g. sustainable diets, food waste), little is known about the contribution of different cooking and preparation methods (e.g. oven, hob, pressure cooker pots), and how these practices might impact the footprint of diets.

So far, cooking methods have been briefly studied mainly as one of the stages of product's life cycle assessments. For example, Frankowska et al. (2019a,b) have shown that in the UK the contribution to climate change of cooking and preparation methods vary from up to 20% in the case of meat products to up to 40% in the case of vegetables. Similarly, for ready meals, cooking and preparation methods could increase GHGe by 35% for chicken roast dinner (Schmidt Rivera et al. 2014) and by 18% for roast beef and Yorkshire pudding (Reynolds et al. 2017). However, an evaluation and comparison of the various cooking and preparation methods has not been done yet to our understanding.

There is a knowledge-disconnection between the food consumed (diets) and the cooking practices which has not been yet investigated. This poster presents the contribution of different cooking and preparation methods to the environmental impacts of 30 food items commonly consumed in the UK. This estimation draws on data that was collected from a UK wide representative sample survey of cooking habits and food practices (n=524). Impacts of food cooking and preparation methods are compared to their contribution to the overall impact of food consumption. The outcomes highlight

what recommendations need to be made to households and food manufacturers to reduce both climate change and energy use while promoting more sustainable diets and consumption practices.

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[10] MEATS AND ULTRA-PROCESSED FOODS IN THE BRAZILIANS' DIET: POTENTIAL TO REDUCE CARBON FOOTPRINT AND WATER FOOTPRINT BY ADAPTING THE EFFECTIVE FOOD CONSUMPTION WITH CANCER PREVENTION RECOMMENDATIONS

Josefa Maria Fellegger Garzillo; Priscila Pereira Machado; Maria Laura da Costa Louzada; Carla Adriano Martins; Renata Bertazzi Levy; Carlos Augusto Monteiro

World Cancer Research Found International recommends eat at least 400g of fruits and vegetables daily; limit red meat between 350 to 500g per week; avoid processed meats, sugary drinks and ultra-processed foods to prevent cancer. How much these recommendations would contribute to reduce carbon and water footprints from average food consumption in Brazil was estimated, also analyzing scenarios of effective consumption of meats (except fish). Using food consumption data of the Brazilian population (≥ 10 years, $n = 34,003$) from the National Household Budget Survey (2008-09) and the Table of Foods and Culinary Preparations Footprints of the Center for Epidemiological Research in Nutrition and Health, environmental impacts were estimated. The average food intake of Brazilians was compared to six scenarios equalized in 2000kcal (a simulated diet based on recommendations and quintiles of population strata according to dietary energy intake from meats). The average consumption was: fruits (186g), vegetables (88g), red meat (77g), processed (9g) and ultra-processed (11g) meats, with 18.4% of caloric intake from ultra-processed drinks and foods. The carbon (4.1kgCO₂eq) and water (4124 liters) footprints estimated for the average Brazilian diet were, respectively, 17% and 18% higher compared to the footprints for the simulated scenario with recommendations. Quintiles (Q1 and Q2) with lower meats intake (red: 6g and 46g; processed: 0.4 and 3g; and ultra-processed: 2 and 8g) presented the lowest carbon (2.1 and 3.2 kgCO₂eq) and water (2184 and 3359 liters) footprints. However, the consumption of vegetables with protective effects remained low and the caloric intake from ultra-processed foods was above the average (22% and 23%). Adapting the average food consumption of Brazilians to WCRFI recommendations would reduce annually 51 GgCO₂eq and 54,239 km³ of water considering 200 million people. In the Brazilian context, adherence to these recommendations would protect population's health while reducing environmental impacts.

[11] EATING AWAY AT CLIMATE CHANGE WITH NEGATIVE EMISSIONS: REPURPOSING UK AGRICULTURAL LAND TO MEET CLIMATE GOALS

Helen Harwatt¹ and Matthew N Hayek²

¹ *Animal Law & Policy Fellow, Animal Law & Policy Program, Harvard Law School*

² *Department of Environmental Studies, New York University*

Radical action, far beyond that currently planned, is required to reduce greenhouse gas (GHG) emissions steeply and rapidly in line with the Paris Agreement. Limiting warming to 1.5°C above pre-industrial temperatures with little or no overshoot additionally requires substantial carbon dioxide removal (CDR) from the atmosphere. The most readily deployable CDR option at scale in the UK is the restoration of its native forests – an option requiring large areas of land. Animal agriculture is the biggest land user in the UK, occupying 48% of all UK land.

Combining existing published datasets into a new spatial analysis, we estimate the CDR potential of returning a portion of UK land currently used for animal agriculture to forest cover in two scenarios. Our first scenario maximises CDR by restoring land currently under permanent pasture and cropland used to produce farmed animal feed to forest. Our second scenario trades off some CDR in order to keep all current cropland in production, allowing for the repurposing of animal feed cropland for increased and diversified crop production for human consumption. Reforesting pasture and feed cropland in scenario 1 delivers a CDR of 4,472 million tonnes CO₂, equivalent to 12 years of current UK CO₂ emissions. In scenario 2, reforesting land currently devoted to pasture results in CDR of 3,236 million tonnes CO₂, equal to offsetting 9 years of current UK CO₂ emissions. In relation to the 1.5°C budget, CDR extends the permissible budget by 75% to 103%, for scenarios 2 and 1 respectively, up to 2050.

Restoring a portion of agricultural land currently used for farmed animals back to native forest would contribute substantially to aligning UK GHGs with the Paris Agreement, and provide new opportunities for diversifying food production. Reforestation on this scale would transform the UK landscape, providing additional benefits including habitats for the reintroduction of wildlife. The multitude of potential benefits provides opportunities for joining up policy across climate change mitigation, agriculture, food, public health and rewilding.

[12] HOUSEHOLD FOOD WASTE SIMULATION MODEL: INVESTIGATION OF INNOVATIONS TO REDUCE MEAT AND DAIRY FOOD WASTE

Cansu Kandemir¹, Tom Quedstedt², Christian J. Reynolds¹, Karen Fisher², Rachel Devine³

¹ *The University of Sheffield, UK*

² *Waste & Resources Action Programme (WRAP), UK*

³ *Royal Holloway, University of London, UK*

Decreasing food and drink waste in the home can have a significant positive environmental and economic impact. However, few empirical studies have been performed on this issue, largely due to the cost and resources involved. This study describes a modelling method that can incorporate complex household dynamics and allow challenging questions regarding household food waste levels to be answered. The results can help governments and businesses to prioritise the actions that will be the most effective and efficient in reducing the amount of food being waste in the home.

At LEAP we will present preliminary results of the “household simulation model” a collaboration between the University of Sheffield and WRAP, UK. The results illustrate how product innovation and collaboration between academia, policy makers and industry can result in potentially large reductions in food waste, and positive environmental impacts.

In this poster we present the findings related to reducing the household food waste of meat and dairy products. Results include showing that increasing the open shelf life of hard cheese by one week can decrease the waste level by approximately up to 15 percentage points (from 17% to 2.3% waste); and that consuming only smaller multi-pack yogurts can decrease waste level by up to 25%, compared to only consuming single big pots.

[13] IMPROVING INCENTIVES FOR FARMERS TO PROTECT NATIVE VEGETATION IN MATO GROSSO, BRAZIL

Laura Kehoe^{1,2}, Joe Kiesecker¹, Charles Godfray², Leandro Baumgarten¹, Julia Mangueira¹, Jim Oakleaf¹, Mike Clark²

¹ *The Nature Conservancy*

² *University of Oxford*

Meat production is the number one cause of deforestation in Brazil. With an increasing demand for meat and livestock feed, farmers are expanding production into the remaining natural areas on their land. The decisions farmers make has a huge impact: over half of Brazil's remaining native vegetation is located on private land. These lands store ~105 billion tons of CO₂ equivalents and play a critical role in conserving biodiversity and protecting local livelihoods by maintaining ecosystem services. Sustainable management of these lands is therefore critical in mitigating global climate change and supporting sustainable development goals. With deforestation rates accelerating, farmers urgently need an incentive to protect the remaining native vegetation on their property.

The Brazilian Forest Code is a key piece of legislation that regulates private land use. However, it is very difficult to make amendments to this code. Regulatory mechanisms within the Forest Code, on the other hand, can be defined at a state level and thus have a higher potential for stakeholder uptake and implementation. One promising mechanism currently under development will allow farmers to offset previous illegal deforestation on their own land by buying ecologically equivalent areas on farms that have additional native vegetation.

Mato Grosso is Brazil's leading grains producer and is central to Brazil's booming soybean feed output. Currently, there are no restrictions on what can be accepted as an ecological equivalent aside from the offset area needing to be in the same biome as the illegally deforested area.

We quantify the impact of prioritizing the placement of offsets in areas of high conservation and carbon value. We integrate spatially explicit economic and biophysical data to identify the optimal regulatory framework to maximize wildlife conservation and carbon sequestration. The conservation and economic opportunities arising from our proposed regulatory mechanisms and challenges for their implementation will then be discussed.

[14] A STUDY PROTOCOL: THE HEARTLAND PROJECT: HEALTH, ENVIRONMENT, AGRICULTURE, RURAL DEVELOPMENT: TRAINING NETWORK FOR LAND MANAGEMENT

J. Kennedy^a, H. Sheridan^b, T. Boland^b, E. Hoffland^c, E.R. Gibney^{b,c}, Gracea, B. Lynch^b, O.Schmidt^b, I De Boer^c, R. De Geode^c, J.Gilliland^a, R. Schulte^c, R. Ripoll Bosch^c

^a*Devenish Nutrition*, ^b*University College Dublin*, ^c*Wageningen University*

Livestock production is increasingly in the spotlight due to its impacts on the environment and human health. Global livestock production, specifically ruminant farming, has been associated with land use change, methane emissions, climate change, deforestation and biodiversity loss. At the same time, consumption of livestock proteins exceeds total human protein requirements for a healthy diet in most European Member States.

That said, ruminants are successful converters of biomass unsuitable for direct human consumption (i.e. grasses and forages) into valuable food, including essential macro and micro-nutrients for humans. In addition, while grazing, ruminants contribute to maintaining the landscape, enhancing biodiversity and increasing carbon sequestration.

Therefore, the industry challenge is to develop livestock production systems that simultaneously enhance both environmental and economic sustainability and support a healthy diet for humans. This is a knowledge-intensive process. Therefore, this European Industrial Doctorate programme - HEARTLAND will connect one of the most the industry to the cutting-edge scientific knowledge and maximise the impact of the programme by working closely with experts through communication (to multiple audiences) and dissemination (to potential end-users).

The objectives of HEARTLAND can be summarized as follows:

1. To train a new generation of creative, entrepreneurial and innovative PhD graduates in the multidisciplinary topic of soil to society
2. To design, implement and evaluate a soil, sward, and grazing farm management system aimed at maximising the positive impact on the environment, improving the nutritional and sensory quality of meat, and consequently improving human health in component and systems research
3. To upscale the findings to contribute to the sectoral development of sustainable production systems and land management
4. To communicate, disseminate and exploit the findings.

[15] MEAT INTAKE AND CANCER RISK: PROSPECTIVE ANALYSES IN UK BIOBANK

Anika Knuppel, Keren Papier, Georgina K. Fensom, Paul N. Appleby, Julie A. Schmidt, Tammy Y. N. Tong, Ruth C Travis, Timothy J. Key, Aurora Perez-Cornago

Cancer Epidemiology Unit, Nuffield Department of Population Health, University of Oxford

Background: Red and processed meat has been consistently found to be associated with colorectal cancer, but evidence for other cancer sites is limited and few studies have examined the association with poultry intake. We examined associations between red, processed meat and poultry intake and incidence for 20 cancer sites.

Method: We analysed prospective data from 475,023 participants (54 % women) in UK Biobank, who were cancer-free at baseline and reported their meat intake in a touchscreen dietary questionnaire. Trends in risk across baseline meat intake categories were calculated by assigning a mean value to

each category using re-measured meat intakes in a subsample (15 %) that completed ≥ 3 web-based 24h recalls. Multivariable-adjusted Cox regressions were used to determine the association between baseline meat intake and cancer incidence.

Results: During a mean follow-up of 6.9 years, 28,955 participants were diagnosed with any type of cancer. Red and processed meat intake was positively associated with risk of colorectal cancer (hazard ratio (HR) per 70 g/day higher intake of red and processed meat 1.31, 95%-confidence interval (CI) 1.14-1.52). Red meat intake was positively associated with risk of breast cancer (HR per 50 g/day higher intake 1.12, 95%-CI 1.01-1.24) and risk of prostate cancer (HR per 50 g/day higher intake 1.15, 95%-CI 1.03-1.29). Poultry intake was positively associated with risk of cancers of the lymphatic and haematopoietic tissues (HR per 30g/day higher intake 1.16, 95%-CI 1.03-1.32). Only the association with colorectal cancer risk was robust to Bonferroni correction for multiple comparisons.

Conclusion: Higher intake of red and processed meat was associated with a higher risk of colorectal cancer. Although the positive associations of red meat with breast and prostate cancer and poultry with cancers of the lymphatic and haematopoietic tissues did not survive correction for multiple testing, they require further investigation.

[16] CHILDHOOD OBESITY AND CLIMATE CHANGE IN THE UK - THE CONTRIBUTION OF ANIMAL AND NON-ANIMAL PROTEIN SOURCES

A. Kluczkowski¹, C.J. Reynolds², A. Frankowska¹, J. T. da Silva^{3,4}, R. Levy³, F. Rauber⁵, X. Schmidt Rivera⁶, S.L. Bridle¹

¹*Department of Physics and Astronomy, School of Natural Science, University of Manchester, Manchester, United Kingdom*

²*Department of Geography, University of Sheffield, Sheffield, United Kingdom*

³*Department of Preventive Medicine, School of Medicine, University of São Paulo, Brazil*

⁴*Research Institute, HCor, São Paulo, Brazil*

⁵*Department of Nutrition, School of Public Health, University of São Paulo, Brazil*

⁶*Institute of Energy Futures, Brunel University London, London, United Kingdom*

Obesity and overweight in children and adolescents have reached 28% in the UK in 2016 (Health Survey for England, 2017). A major public health issue, childhood obesity is associated with mental health related conditions (Conolly & Davies, 2018). Apart from being a health concern, the increasing number of childhood obesity might also have serious implications on the environment. The food system currently contributes to about a quarter of global greenhouse gas emissions (GHGE), with generational and individual dietary choices influencing the magnitude of associated GHGE. According to Notarnicola et al. (2017) animal protein products share a major part of the total environmental impacts of diets. However, little is known about the relationship between obesity, diets (in particular products high in animal protein) and climate change.

Therefore, this poster aims to identify the connection between the body mass index (BMI) of children under 10 years old and the GHGE of their dietary choices with a focus on GHGE from animal and non-animal protein sources.

We use the UK National Diet and Nutrition Survey (NDNS) database from 2008-2009 to determine the number of obese and non-obese children (under 10 years of age) using the body mass index

(BMI). We then estimate GHGE associated with diets of these population group using data from Bates et al. (2019). Finally, we evaluate the relationship between obesity and GHGE to understand the impacts of unhealthy diets on climate change stressing the linkage to animal and non-animal protein sources.

The results of this study are of importance to understand the connections between obesity and GHGE supporting the concept of sustainable diets by showing that health concerns such as obesity and environmental impacts are directly intertwined.

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[17] GIVING PORK THE CHOP: RESPONSE INHIBITION TRAINING TO REDUCE MEAT INTAKE

Natalia Lawrence, Bethany Camp
Psychology, University of Exeter

Meat consumption is damaging to the environment, human health and animal welfare. Despite a growing interest in reducing meat intake, many people eat too much. This is partly due to the pleasure people associate with eating meat, which can make it hard to resist. Previous research in psychology has used computerised response inhibition training (inhibiting key press responses to food pictures) to reduce the reward value (liking) of snack foods and decrease intake. However, inhibition training has not yet been applied to meat. We investigated whether an internet-delivered response inhibition training task using meat pictures (active condition) could help people to reduce their meat intake relative to an inhibition training task with non-food pictures (control condition). Participants (N=81) were meat eaters who had some desire to reduce their meat intake. They completed four 10-minute training sessions in one week. Participants in the active group inhibited responses to meat and responded to pictures of fruits and vegetables and non-food items. Meat intake was measured via self-report using food frequency questionnaires at pre- and one month post-training, and using a daily meat diary for one week during training. We also measured training effects on liking of meat and other foods. Results showed a reduction in the frequency of meat intake over one month in both groups, with the active group showing a significantly larger decrease. Both groups also showed reduced liking of meat, with active participants showing a significantly greater reduction in liking of food in general. Reduced meat intake was associated with decreased liking of meat in active but not control participants. Groups did not differ in meat intake during the training week. These findings suggest that meat response inhibition training could help people to reduce their meat intake. Future research should conduct larger randomised controlled trials with longer-term outcome measures.

[18] LOOKING AFTER LAMBS: IDENTIFYING THE OPTIMUM TYPOLOGY FOR TREATMENT OF FOOTROT

Kate Lewis¹, Laura Green²

¹ *University of Warwick*

² *University of Birmingham*

Lameness in sheep is a health, welfare and economic concern, with most lameness attributable to footrot, an infectious bacterial disease caused by *Dichelobacter nodosus*. Current best practice treatment is antibiotic injection and spray of individual ewes, with no foot trimming within three days of onset of lameness. Latent class (LC) analysis was used to identify typologies of treatment for footrot in ewes and lambs to identify treatments associated with lower prevalence of lameness (PoL). Differences in PoL between classes were investigated using Wilcoxon tests with Benjamini-Hochberg adjusted p-values.

For ewes, two typologies of treatments for footrot were significantly associated with lower PoL. In LC1 the geometric mean (GM) PoL was 1.8%, (95% CI 1.0-3.1) and GM prevalence of interdigital dermatitis (ID) lesions was 1.1% (95% CI 0.5-2.3), and farmers used treatment infrequently. These results suggest that some lameness was not infectious and farmers did not treat ewes because they were rarely lame. In LC2, the GM PoL was 3.2% (95% CI 2.9-3.7), and the GM prevalence of ID lesions was 4.0%, (95% CI = 3.0-5.3) and farmers used 'best practice' treatment, indicating 'best practice' treatment was reasonably effective at maintaining lameness at a prevalence comparable to flocks in LC1 with fewer ID lesions. There were two other typologies of treatment significantly associated with higher GM PoL (3.9% (95% CI = 3.5-4.4), and 4.2% (95% CI = 3.9-4.5)), both involving delayed treatment and use of foot trimming. Typologies for treatment of lambs were similar to those for ewes, but only one typology was associated with lower GM PoL (1.0% (95% CI 0.6-1.7)), and was characterised by low use of treatment. No LC typology followed 'best practice' for lambs, indicating potential to improve advice on use of 'best practice' treatment of lame lambs, assuming it would be as effective as in ewes.

[19] DEMYSTIFYING THE UNIT DEPENDENCY OF LCA METRICS THROUGH BETTER UNDERSTANDING OF HUMAN NUTRITION

G.A. McAuliffe, T. Takahashi, M.R.F. Lee

Rothamsted Research

Environmental impacts of agricultural systems have traditionally been calculated for each mass of food produced or, in case of protein-rich commodities, for each mass of protein produced. However, this approach ignores the fact that a change in farming practices often disrupts the flow of nutrients within the production environment, ultimately altering the nutritional value of the final product too. Thus, agri-food systems optimised under traditional environmental criteria could only be suboptimal.

To overcome this issue, we developed a new framework of life cycle assessment (LCA) with nutrient density score as the functional unit, under which nutritional consequences of different farming systems can be internalised into the resultant environmental footprint to better inform commercial farmers. Methodological improvements comprised two parts: first, the nutrient flow was tracked across the entire value chain, both upstream and the downstream of the farm, so that the

nutritional composition of the final product could be differentiated between food produced under different farm management strategies. Second, to reflect the marginal nutritional value of the product to a particular individual, a computationally novel 'modular plate' approach was introduced to estimate commodity-level carbon footprints under various dietary contexts.

A case study based on common protein-rich food systems in the UK revealed that adoption of the new approach could often alter the main conclusion of an analysis, with relative environmental impacts of cattle systems typically lowered due to the higher mineral and vitamin densities associated with their products. However, this trend was sensitive to the serving size of the meal as well as the selection of non-protein 'side dishes' consumed alongside, indicating the importance of isolating footprints attributable to overconsumption of a particular commodity from its consumption in an adequate quantity. Interdependency between these results and the recent University of Oxford study on methane gas fluxes will also be discussed.

[20] UNCONVENTIONAL EATING BEHAVIOUR AND ITS EFFECT ON BRAIN CIRCUITS AND ON GUTBRAIN-COMMUNICATION

Evelyn Medawar^{1,2,3}

¹ *Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany*

² *Berlin School of Mind and Brain, Humboldt-Universität zu Berlin, Germany*

³ *Charité - Universitätsmedizin Berlin; Humboldt-Universität zu Berlin, Germany*

Intro. Meat-restrictive eating patterns are debated to either convey health benefits or risks (reviewed in Medawar et al., 2019). Recent studies indicated conflicting evidence for emotional health, including higher depression and higher neuroticism in vegetarians (Agarwal et al. 2015; Beezhold et al. 2015; Forestell and Nezelek 2018; Hibbeln et al. 2018; Matta et al. 2018; Molendijk et al. 2018). Recently, it has been suggested that not meat-restriction per se, but the number of excluded food groups was associated with higher depressive scores (Matta et al. 2018).

Aim. The aim of my PhD project is to assess, whether plant-based diets, i.e. a high-fiber diet, influence our decisions of what we would like to eat. We postulate that potential effects are mediated by the gut microbiome. The project is divided into 4 sub-studies: in observational studies (study 1+2) we investigate the effect of a single meal choice on well-being and satiety. In a cross-sectional study (study 3) we investigate whether the frequency of consumption of animal-derived products is associated with weight status, emotional health and personality traits. In a double-blinded cross-over intervention study (study 4) we examine, whether a 2-week high-fiber dietary intervention affects food wanting, memory performance and their neural correlates as well as brain structure and microstructure. Further, we test whether biomarkers, such as microbial status, serum levels of gastrointestinal hormones, metabolic and inflammatory markers mediate the observed effects.

Outlook. Preliminary results from study 3 indicate that a putative link between animal-restricted diet patterns and depressive symptoms may be explained by differences in demographics and personality traits. This may be in part due to confounding effects between obesity and depression, as these two conditions are assumed to share not only certain symptoms but also mechanistic pathways (Milaneschi et al. 2019; Ouakinin, Barreira, and Gois 2018), and both weight gain and weight loss may relate to depressive symptoms (McElroy et al. 2004).

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[21] IMPLEMENTATION OF SUSTAINABLE SCHOOL FEEDING IN BAHIA STATE, BRAZIL, AS A STRATEGY FOR EFFICIENT USE OF PUBLIC RESOURCES

Camilla Almeida Menezes^{1,2}, Letícia Baird¹, Patrícia Rafaela Santana Carvalho¹, Paulo Victor Gonzaga Pinheiro^{3,4}, Renata Maria Rabelo da Silva Lago⁴, Alexvon Nunes Gomes⁴, Ana Marice Teixeira Ladeia⁴, Nelzair Vianna⁵, Ricardo Riccio⁵, Dalila Luciola Zanette⁵

¹ Public Ministry of Bahia State, Brazil, ² Gonçalo Moniz Institute, Fiocruz Bahia, Brazil

³ Humane Society International, ⁴ Bahiana School of Medicine and Public Health, Bahia, Brazil

⁵ Public Health, Gonçalo Moniz Institute, Fiocruz Bahia, Brazil

Background: Sustainable food patterns are those which cause low environmental impact, as plant-based diet. In Brazil, Public Ministry of Bahia State, after identifying nutritional disorders in school population, proposed the Sustainable School Program (SSP) which aims to improve school meals quality; promote nutritional, environmental and humanitarian education; prevent diseases; and rationalize public financial and environmental resources.

Methods: SSP was implemented in 2018 in 4 cities - Serrinha, Barrocas, Biritinga and Teofilândia. Local implemented actions included sensitization of managers and civil society; strengthening family farming, which is predominantly vegetable-producing; schools physical structure improvement; and

cook training. Sustainable menu implementation was initiated in 2019 and foresees gradual replacement of animal products by vegetables until the end of 2020, when it is expected to be at least 80% plant-based. Two research institutions are responsible for student's health monitorization through anthropometric, clinical and laboratory evaluation. Initial data collection happened in March 2019 and the others are scheduled for 2020.

Preliminary results: SSP scope included 167 schools, 435 school cooks and 32,736 students. Preliminary health monitoring results are expected by the end of this year. To date, schools have plant-based meals twice a week and more than 10 preparations have been tested and approved, such as peanut milk, bean burgers and vegetable feijoada. Meals were developed to respect local eating habits and have been gradually inserted into the menus in order to rescue traditional crops and strengthen the small family farmer.

Perspectives: One of the constitutional duties of public management is public resources rationalization, based on the principle of efficiency. Since literature describes plant-based diets are not only more socially, environmentally and economically sustainable, but also energetically efficient, implementation, monitoring, and biological plausibility verification of interventions like that are extremely relevant for country development.

[22] MEAT, FRUIT AND VEGETABLE CONSUMPTION IN SUB-SAHARAN AFRICA: A SYSTEMATIC REVIEW AND META-REGRESSION

D.O. Mensah¹, R.A. Nunes¹, T. Bockarie, R. Lillywhyte², and O. Oyeboode¹

¹ *Health Sciences Division, Warwick Medical School, University of Warwick*

² *School of Life Sciences, University of Warwick*

Background: The dietary choices we make affect our personal health and have consequences for the environment, both of which have serious implications for the 2030 Sustainable Development Agenda. There is a strong consensus that cutting on meat and dairy products in favour of fruit and vegetables and other plant-based diets would offer dual health and environmental benefits. In global reviews, the literature on meat, fruit, and vegetable consumption in sub-Saharan Africa (SSA) is limited. It is therefore essential to quantify meat, fruit, and vegetable consumption in sub-Saharan African populations.

Scope and approach: We systematically searched six databases to identify studies reporting meat, fruit and/or vegetable consumption in sub-Saharan African populations. Using STATA SE 15, random effects meta-regression analyses were used to test the effect of year of data collection and method of data collection on population meat, fruit, and vegetable consumption. We also tested any association between age, sex, urban/rural residence or a country's economic development, and population intake of meat, fruits and/or vegetables.

Key Findings: Richer SSA countries were likely to consume more meat ($\beta = 36.76$, $p=0.04$) and vegetables ($\beta = 43.49$, $p=0.00$) than poorer countries. Vegetable intake has increased dramatically over the last three decades from $\approx 10g$ to $\approx 110g$ ($\beta = 4.43$, $p=0.00$). Vegetable ($\beta = -25.48$, $p=0.00$) consumption was higher in rural than urban residents. Although the trend of meat consumption has gone up ($\approx 25g$ to $\approx 75g$), the trend is non-significant ($\beta = 0.63$, N.S.). Daily average per capita meat consumption was however above recommended 70g, while fruit and vegetable intake remain below WHO's recommendation. No clear differences in consumption were noticed between sexes.

Conclusion: While dietary changes in SSA may offer the large absolute benefits, consideration of the magnitude of dietary change, particularly increasing meat consumption, will need to occur to ensure policy and interventions support the reduction of under-nutrition and micronutrient deficiencies without worsening NCD prevalence and environmental impacts.

[23] A PILOT METHOD LINKING GREENHOUSE GAS EMISSION DATABASES TO THE FOODEX2 CLASSIFICATION

C.J. Reynolds⁴, X. Schmidt Rivera³, A. Frankowska⁶, A Kluczkowski⁶, J. T. da Silva^{5,6}, S. L. Bridle⁷, R. Levy⁶, F. Rauber⁶, V. P. Quadros¹, A. Balcerzak¹, R. F. Sousa¹, M. Ferrari², C. Leclercq¹, B. Koroušič Seljak⁸, Tome Eftimov^{8,9}

¹ *Nutrition and Food Systems Division, Food and Agricultural Organization of the United Nations, Rome*

² *Research Centre for Food and Nutrition, Council for Agricultural Research and Economics, Rome*

³ *Institute of Energy Futures, Brunel University London*, ⁴ *Department of Geography, University of Sheffield*, ⁵ *HCor Research Institute, São Paulo Brazil*, ⁶ *School of Medicine, University of São Paulo, Brazil*, ⁷ *School of Physics and Astronomy, University of Manchester*, ⁸ *Computer Systems Department, Jožef Stefan Institute, Ljubljana, Slovenia*, ⁹ *Department of Biomedical Data Science and the Center for Population Health Sciences, Stanford University*

Information related to greenhouse gas emissions (GHGE) embodied in the production and consumption of multiple foods (including meat and dairy) have become more available in recent years thanks to literature reviews and meta-analysis of life cycle assessment literature. However, there is limited matching of this information to dietary databases. This linkage is needed to investigate the climate change impacts of different dietary patterns, to formulate policies for helping to shift population's eating habits towards healthy and sustainable diets.

Linking a dietary database to GHGE is time consuming as well as effortful. These activities are typically not well documented which makes them hard to replicate. Furthermore, as each country has multiple dietary consumption and purchase surveys (which potentially are redesigned between each survey version), there is a potential for coding GHGE to global dietary databases resulting in months of labour. This is a major limitation to speeding up policy making promoting food sustainability, and making information related to global dietary sustainability widely available.

Many global dietary databases are already harmonised to be comparative using the FoodEx2 system classification, a description and classification system developed and maintained by EFSA¹. It is currently used at global level with the support of FAO and WHO². FoodEx2 consists of a vocabulary of foods with assigned codes structured in a hierarchical manner, allowing the classification and description of foods reported in different types of data (e.g. consumption or production method, composition etc.). The linkage of GHGE databases to individual FoodEx2 codes would allow rapid translation to any previously harmonised FoodEx2 food survey.

This poster reports the results of a pilot study that mapped aggregated GHGE databases^{3,4} to the FoodEx2 classification. As GHGE databases of food products vary in scope of assessment and system boundary, this lead to differences in final GHGe values for each FoodEx2. These database differences in reported dietary GHGE are compared using different EU food consumption databases. The results

suggest that this method allows us to provide rapid global GHGE related to diets comparing multiple GHGE data sources.

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[24] ENVIRONMENTAL FOOTPRINTING OF UPLAND LAMB PRODUCTION

Hollie Rachael Riddell¹, Dave Chadwick¹, David Styles¹ and Bob Rees²

¹ School of Natural Sciences, Bangor University, Wales

² Carbon Management Centre Scotland's Rural College (SRUC), Edinburgh

The environmental impacts of agricultural systems, particularly those associated with livestock production, are receiving increasing attention worldwide. This study will explore the emissions (nitrous oxide (N₂O) from urine and dung and enteric methane (CH₄)) and other environmental impacts associated with lamb production in UK upland areas. Measured and collected data will be used to determine improved emission factors for upland systems, allowing development of a subsequent environmental footprint using Life Cycle Assessment (LCA) approaches. The study will also explore ecosystem services and upland management scenarios including mitigation options and environmental trade-offs between land uses. Methodologies include use of a GreenFeed system to quantify enteric methane from grazing sheep. Mobile soil gas measurement systems will be used to measure N₂O emissions from sheep urine/dung. LCA techniques will be applied to determine the environmental footprint of lamb production and draw comparisons between upland and lowland systems. Field trials in lowland and upland pastures are currently underway and differences are expected between the areas due to environmental context and land management differences. Lower urine N₂O emissions factors are expected for upland vs. lowland pastures, however ruminant CH₄ emissions may be higher due to poorer pasture quality. Overall, the environmental impacts of upland systems may compare favourably against lowland systems, particularly when wider ecosystem services delivered by extensive livestock management in upland areas are considered. This work is intended to support policy decision making for the future of the nationally significant upland areas and aid in improving the environmental sustainability of the sheep industry.

[25] PROMOTING 'BETTER' MEAT AND DAIRY: GLOBAL ANIMAL WELFARE ASSURANCE

Elizabeth Rowe¹, Jeremy Rix², David Main³, Jessica Stokes³, Joe Bailey⁴, Arnja Dale⁵, Susanne Maassen⁶, Anne Malleau⁷, Kate Stills⁸, Lydia Stratton⁴, Gemma Willemsen⁹, Siobhan Mullan¹
¹Bristol Vet School, UK; ²OKO Agency, UK; ³Royal Agricultural University, UK; ⁴RSPCA Assured, UK; ⁵SPCA New Zealand, NZ; ⁶Beter Leven, NL; ⁷Global Animal Partnership, USA; ⁸Soil Association, UK; ⁹Dierenbescherming, NL

The scientific evidence is clear that we need a reduction in meat and dairy consumption in Western countries such as the UK, in order to protect not only our own health but that of the planet too. This is also important in developing countries to prevent consumption levels from rising above those that are best for human and planetary health. The 'less and better' approach to consuming meat and dairy products has been advocated by many organisations: we should eat less meat and dairy, and when we do eat it, we should choose 'better' products. Higher animal welfare standards are a vital part of the 'better' facet of this approach, and one of the best ways of choosing products with higher welfare standards is to choose those certified by a higher welfare farm assurance scheme. However, many different higher welfare schemes exist nationally and internationally, and their standards do not always concur. This can lead to confusion amongst consumers and can be especially challenging for businesses making purchases on a global scale. Global Animal Welfare Assurance (GAWA) is an alliance of five higher welfare certification schemes operating in Europe, North America and Australasia, along with the UK's leading animal welfare charity the RSPCA, and academics from the University of Bristol and the Royal Agricultural University (UK), who share the common vision of increasing the production and consumption of higher animal welfare products. The vision is to create an authentic global source of higher welfare products, which will increase demand by improving the identification, availability and supply of such products. GAWA will provide the first independent evidence-based higher welfare certificate of authenticity, providing higher welfare transparency throughout the supply chain to leverage buyers (such as food retailers, food services, public procurement organisations) towards higher welfare products. This poster describes the development of GAWA.

[26] MEAT CONSUMPTION AND RISK OF HOSPITALIZATION FOR 25 COMMON HOSPITAL CONDITIONS: RESULTS FROM THE UK BIOBANK

Keren Papier, Georgina K Fensom, Anika Knuppel, Timothy J Key, Aurora Perez-Cornago
Cancer Epidemiology Unit, Nuffield Department of Population Health, University of Oxford

Aim: To assess the association between meat (red meat, processed meat, and poultry) intake and risk of hospital admission or death for 25 common conditions (other than cancer).

Methods: We used data for 475,025 participants from UK Biobank with information on meat intake at baseline (2006-2010) and linked hospital admissions and mortality data. For a sub-sample (n=69,119), dietary intakes were re-measured >3 times using an online 24-hour questionnaire. We assigned the mean values from the re-measured intakes to the baseline meat intake categories for all participants, and calculated incident hospitalization or death in relation to meat consumption using Cox regression. Multiple testing was accounted for using Bonferroni correction.

Results: After a mean follow-up of 8 years, a higher consumption of red and processed meat was associated with higher risks of ischaemic heart disease (IHD) [Hazard ratio (HR) per 70 g/day higher intake 1.14, 95% confidence interval (CI) 1.06-1.23], diabetes (1.29,1.19-1.40), diverticular disease (1.18,1.11-1.27), colon polyps (1.09,1.05-1.13), and pneumonia (1.28,1.16-1.42). Red meat intake was inversely associated with risk of iron deficiency anaemia (IDA) (HR per 50g/day higher intake 0.77, 0.69-0.86). Higher poultry intake was associated with higher risks of diabetes (HR per 30g/day higher intake 1.13,1.06-1.20), diverticular disease (1.10,1.04-1.17), gastro-oesophageal reflux disease (1.15,1.06-1.24), and gastritis and duodenitis (1.11,1.05-1.17), and a lower risk of IDA (0.80,0.73-0.87).

Conclusions Higher red and processed meat consumption was associated with higher risks of IHD, diabetes, diverticular disease, colon polyps, and pneumonia, and a lower risk of IDA. Higher poultry consumption was associated with higher risks of diabetes, diverticular disease, gastro-oesophageal reflux disease and gastritis and duodenitis, and a decreased risk of IDA. Our findings for red and processed meat are in line with previous research, but evidence for associations between red and processed meat and pneumonia, and for poultry and health are limited, thus warranting further study.

[27] COMPARISON OF MAJOR PROTEIN-SOURCE FOODS AND OTHER FOOD GROUPS IN MEAT-EATERS AND NON-MEAT-EATERS IN THE EPIC-OXFORD COHORT

Keren Papier¹, Tammy YN Tong¹, Paul N Appleby¹, Kathryn E Bradbury², Georgina K Fensom¹, Anika Knuppel¹, Aurora Perez-Cornago¹, Julie A Schmidt¹, Ruth C Travis¹, Timothy J Key¹

¹ *Cancer Epidemiology Unit, Nuffield Department of Population Health, University of Oxford*

² *National Institute for Health Innovation, The University of Auckland, Auckland, New Zealand*

Differences in health outcomes between meat-eaters and non-meat-eaters might relate to differences in dietary intakes between these diet groups. We assessed intakes of major protein-source foods and other food groups in six groups of meat-eaters and non-meat-eaters participating in the European Prospective Investigation into Cancer and Nutrition (EPIC)-Oxford study.

Methods: Data were from 30, 239 participants who answered four questions regarding their consumption of meat, fish, dairy or eggs and completed a food frequency questionnaire (FFQ) in 2010. Participants were categorized as regular meat-eaters (>50 grams of total/any meat per day: n=12,997); low meat-eaters (<50 grams of total/any meat per day: n=4,650); poultry-eaters (poultry but no red meat: n=591); fish-eaters (no meat but consumed fish: n=4,528); vegetarians (no meat or fish: n=6,672); and vegans (no animal products: n=801). FFQ foods were categorised into 45 food groups. Analysis of variance was used to test for differences between age-adjusted mean intakes of each food group by diet group.

Results: We found that regular meat-eaters, vegetarians and vegans, respectively, consumed about a third, quarter and a fifth of their total energy intake from high protein-source foods. Compared with regular meat-eaters, low and non-meat-eaters consumed higher amounts of high-protein meat alternatives (soy, legumes, pulses, nuts, seeds) and other plant-based foods (whole grains, vegetables, fruits) and lower amounts of refined grains, fried foods, alcohol, and sugar-sweetened beverages.

Discussion: Overall, our results suggest that there were large differences in the amounts and types of protein-rich and other foods eaten by regular, low and non-meat-eaters. These findings provide insight into potential nutritional explanations for differences in health outcomes between diet groups.

[28] MEAT REDUCERS ARE PERCEIVED POSITIVELY

Vibhuti Patel^{1, 2, 3}, Nicola Buckland¹, Helen Kennedy²

¹ *Department of Psychology, University of Sheffield*, ² *Department of Sociological Studies, University of Sheffield*, ³ *The Grantham Centre for Sustainable Futures*

High meat intake poses a significant threat to human and planetary health (Willett et al., 2019). Alongside developing technological innovation, individual behavioural changes are crucial to reduce these threats (e.g. Hedenus et al., 2014). As such, ways to reduce consumer demand for meat products must be identified. Social norms are an untapped yet promising tool for promoting meat reduction, given their demonstrated influence in adjusting pro-environmental and eating behaviours (Cruwys et al., 2015; Farrow et al., 2017). Dynamic social norms, or changing norms, have been demonstrated to promote reduced meat intake (Sparkmann & Walton, 2017), however there is, to date, no empirical evidence on the role of descriptive norms on reducing meat consumption. This research paves the way for such investigation, by exploring perceptions of the norm referent group – meat reducers. Evidence suggests that conformity to social norms is affected by perceptions of the norm referent group, where normative messages may be rejected if they reflect a group that is undesirable or non-aspirational (e.g. Berger & Rand, 2008). While those who practice meat-free diets have historically been perceived negatively (e.g. MacInnis & Hodson, 2017), the recent rise in popularity of meat-free or low meat diets may have shifted such perceptions. This research aims to determine the favourability, perceived personality impressions, and perceived group membership of meat reducers. The first study (registered on Open Science Framework, osf.io/ke7sd) uses a free association task to determine associations towards meat reducers (versus vegetarians and habitual meat consumers) by UK adults. The second study uses vignettes to explore personality impressions and perceived group membership (i.e. ingroup versus outgroup) of the same three groups, by university students and staff. Together, this research will provide insight into how meat reducers are perceived, and will inform the development of social norms interventions to reduce meat intake.

[29] A PROSPECTIVE INVESTIGATION OF PLANT FOODS, DIETARY FIBRE AND ISCHAEMIC HEART DISEASE IN THE EPIC COHORT

Aurora Perez-Cornago¹, Francesca L Crowe², Paul N. Appleby¹, Timothy J. Key¹ on behalf of the EPIC-CVD Consortium

¹ *Cancer Epidemiology Unit, Nuffield Department of population Health, University of Oxford*

² *Institute of Applied Health Research, University of Birmingham*

Background: Epidemiological evidence indicates that diets rich in plant foods are associated with a lower risk of ischaemic heart disease (IHD), but there is sparse information on fruit and vegetable subtypes and sources of dietary fibre.

Aim: To assess the associations of major plant foods, their subtypes and dietary fibre with risk of IHD in EPIC.

Methods: We conducted a prospective analysis of 490,311 men and women in ten European countries without a history of myocardial infarction or stroke at recruitment. Dietary intake was assessed using validated questionnaires, calibrated with 24-hour recalls. Multivariable Cox regressions were used to estimate hazard ratios (HR) of IHD.

Results: During a mean of 12.6 years follow-up, we documented 8504 myocardial infarction cases or IHD deaths. There was a lower risk of IHD with a higher intake of fruit and vegetables combined (HR per 200 g/day higher intake 0.94, 95% CI: 0.90-0.99, P-trend=0.009), total fruits (per 100g/day 0.97, 0.95-1.00, P-trend=0.021) and bananas (per 50g/day 0.91, 0.86-0.97, P-trend=0.006); there were no associations with other fruit subtypes. Risk was lower with higher intakes of nuts and seeds (per 10g/day 0.90, 0.82-0.98, P-trend=0.020), total fibre (per 10g/day 0.95, 0.85-0.98, P-trend=0.015), fruit and vegetable fibre (per 4g/day 0.95, 0.91-0.99, P-trend=0.022), and fruit fibre (per 2 g/day 0.97, 0.95-1.00, P-trend=0.045). No associations were observed between vegetables, vegetables subtypes, legumes, cereals and IHD risk.

Conclusions: Results from this large prospective study suggest that higher intakes of fruit and vegetables combined, total fruit, bananas, nuts and seeds, total fibre, fruit and vegetable combined fibre, and fruit fibre are associated with a lower risk of IHD.

[30] THE EFFECTS OF ENVIRONMENTAL SUSTAINABILITY LABELS ON SELECTION, PURCHASE, AND CONSUMPTION OF FOOD AND DRINK PRODUCTS: A SYSTEMATIC REVIEW

C. Potter¹, A. Bastounis¹, J. Hartmann-Boyce¹, C. Stewart¹, K. Frie¹, K. Tudor¹, F. Bianchi¹, E. Cartwright², B. Cook¹, S. A. Jebb¹

¹ *University of Oxford*, ² *Nanyang Technological University, Singapore*

Background: This review aims to assess the effect of environmental sustainability labels (ecolabels) on consumers' actual and virtual selection, purchase, and/or consumption of more environmentally sustainable food and drink products.

Methods: Seven electronic databases were searched in April 2019 for experimental studies of ecolabels evaluating the above outcomes. Screening, data extraction and data synthesis followed standard Cochrane methods. An adapted version of Cochrane's Risk of Bias (RoB) tool was used to determine the confidence in the effect estimates. We categorised interventions by type (actual v. virtual settings), format (logo, text, or both) and message type (organic, environmentally sustainable, carbon emissions, or other). Methodological heterogeneity precluded meta-analysis. Results were synthesised using vote counting based on direction of effects.

Results: Fifty-six experimental studies (N=39,593 participants, representing 62 interventions) met the inclusion criteria. Fifteen studies assessed actual outcomes and 41 studies assessed virtual outcomes. In 34 interventions the ecolabel was presented as text, 14 as a logo, and 14 used a combination. Twenty-nine interventions tested an organic message, 18 tested an environmentally sustainable message, 14 tested a carbon emissions message, and 11 tested other message types. Thirty-eight studies received a moderate or high RoB rating. Across all 91 outcomes, 74 effect sizes

(ES) favoured intervention conditions, while 17 ES favoured control conditions. The ratio of ES outcomes in favour of intervention compared to control for organic, environmentally sustainable, carbon emissions and 'other' messages was 32:8, 13:3, 14:5, and 15:1, respectively.

Conclusion: Providing information about the environmental impact of food and drink products using a variety of messages and formats encourages demand for more sustainable products.

[31] SOIL QUALITY CHANGES IN A ROTATION WITH OUTDOOR PIGS AND ANNUAL CROPS

Ishwar Pun¹, Marcelo V. Galdos², Pipa Chapman², Lisa Collins²

¹ *School of Biology, University of Leeds*

² *School of Earth and Environment, University of Leeds*

Outdoor pig production accounts for 40% of the UK pig industry. Outdoor pig production practice is preferred because the animals are reared in a natural environment and it is considered good for animal welfare. However, from the environmental perspective there is a concern that this practice may adversely disturb the physical and chemical properties of soil, including soil compaction, nutrient loads, and nitrogen emission/leaching etc. Despite this, there are few studies to date on this and as such a systematic study exploring this issue of wide interest. Here, we aim to study the effect of outdoor pig production practices with crop rotation on the physical and chemical properties of the soil. Crops such as wheat, barley, potatoes, oilseed, and vining peas are cultivated in two years rotation with the outdoor pigs at the University of Leeds' farm. Soil physical and chemical properties were sampled before and after the introduction of pigs to the fieldsites. In addition, weather data, daily temperature, precipitation, solar radiation, and relative humidity have been collected from the on-site meteorological station to capture a more holistic view of the agri-environmental system. Using the DayCent model, we provide an understanding of the complex interactions between soil, climate, and livestock management. This model simulates crop yields, soil organic matter, fluxes of carbon, nitrogen, and phosphorus in different native and managed agricultural systems. The data obtained from this study will be useful to understand to what extent pigs affect the quality of arable land, and the physical and chemical properties of the soil. In the longer term, this research will investigate spatio-temporal changes in crop production, soil organic matter, and nitrous oxide emission. Incorporating this data into the process-based model will overall allow us a better understanding of the harmonies and disharmonies existing between outdoor pig production, crop rotation and climate change.

[32] MODELLING THE IMPACT OF SOCIAL MARKETING CAMPAIGNS TO REDUCE MEAT CONSUMPTION: RESULTS FROM AN AGENT-BASED MODEL

A. Scalco¹, T. Craig², S. Whybrow¹, G. W. Horgan³, J. I. Macdiarmid¹

¹ *Life Course and Population Health, The Rowett Institute, University of Aberdeen*

² *Social, Economic and Geographical Sciences Research Group, The James Hutton Institute, Aberdeen*

³ *Biomathematics and Statistics Scotland, Aberdeen*

High levels of meat consumption are a problem for both health and the environment. Social marketing campaigns are one strategy that could be used to try and change dietary behaviours. This

study aimed to develop a social simulation of consumers' meat consumption, based on a representative population, using agent-based modelling (ABM) to test these types of campaigns.

In this study social marketing campaigns were applied in the workplace (norm-based messaging about health, environment and animal welfare). Agents in the model represent consumers with a range of socio-demographic characteristics and personal views about the impact of meat on the environment, health and animal welfare. The influence of social networks on changing the agents' views was modelled. In the model, the effect of the workplace campaigns on meat consumption as influenced by the views of the agents' peers at work was tested. Also, the likelihood of the effect spreading to other agents in the household was also assessed. Data from the British Attitudes Survey and National Diet and Nutrition Survey were used to empirically ground the model. The outputs included the average weekly consumption of meat and the likelihood of each agent to eat meat. Results suggest that health rather than environment or animal welfare has a greater influence on reducing meat consumption and that successful workplace interventions could indirectly affect other household members through social influence. These types of models can be used to provide important information for the development of interventions and policies designed to reduce meat consumption at the population level.

[33] NMR METABOLIC PROFILE IN MALE MEAT-EATERS, FISH-EATERS, VEGETARIANS AND VEGANS IN EPIC-OXFORD

Julie A. Schmidt, Georgina K. Fensom, Michael V. Holmes, Timothy J. Key, Ruth C. Travis*
Nuffield Department of Population Health, University of Oxford [*Presenting author]

Background: Diets without meat and other animal products such as dairy are becoming more popular and may be associated with lower risk of some non-communicable diseases, incl. coronary heart disease, some cancers and type 2 diabetes. Metabolomics may help us understand the underlying mechanisms. We aimed to investigate differences in circulating metabolites between meat-eaters, fish-eaters (who do not eat meat but do eat fish), vegetarians (who do not eat meat or fish) and vegans (who do not eat meat, fish, egg or dairy).

Methods: In this cross-sectional study of 286 men from EPIC-Oxford, we measured 207 serum metabolite concentrations and ratios using NMR (Nightingale Health, Finland). Differences in mean concentrations and ratios by diet group were tested using ANOVA accounting for confounding and multiple testing (FDR<0.05). We used PLS-DA to investigate separation of metabolic profiles and classification by diet group.

Results: 104 (50.2%) metabolites varied significantly between diet groups, after correction for multiple testing. The strongest differences included those for fatty acids (docosahexaenoic acid [DHA C22:6 n-3], total n-3, polyunsaturated and saturated fatty acids [all lowest in vegans and highest in meat-eaters], linoleic acid [LA C18:2 n-6] and total n-6 fatty acids [both highest in vegans]); cholesterol fractions in sub-classes of VLDL and IDL particles (all lowest in vegans); and sphingolipids (lowest in vegans, followed by vegetarians, then fish-eaters and highest in meat-eaters). Based on metabolic profile, 87.3% of men were correctly classified as vegans or non-vegans. The metabolites predominantly responsible for this separation were fatty acids and cholesterol fractions in VLDL and HDL particles.

Conclusion: Men excluding varying degrees of animal products from their diet have different serum metabolic profiles. We plan to compare the current results with those from a mass spectrometry based platform (Biocrates Lifesciences AG, Austria) and investigate temporal reproducibility of the NMR metabolites.

[34] UCD LYONS FARM LONG-TERM GRASSLAND EXPERIMENT

Helen Sheridan, Alexander Evans, Bridget Lynch, Fionnuala Godwin, Shona Baker, Joe Jones, Paul Murphy, Alan Kelly, Frank Monahan, Edward Jordan, Tommy Boland

School of Agriculture and Food Science, University College Dublin

UCD Lyons Farm, Celbridge, Nass, Co. Kildare, Ireland

Resource use efficiency is key to achieving the UN Sustainable Development Goals as they pertain to ruminant production systems. Over the last 60 years, the majority of temperate agricultural grassland systems have become botanically impoverished, with an increasing reliance on *Lolium perenne* coupled with high nutrient input levels. Recent research has shown the potential agricultural and environmental benefits associated with multi-species grasslands. However, many questions remain to be answered with respect to their composition, establishment, management, and impacts on grazing animal performance and health, and the wider environment. Many of these questions can only be comprehensively addressed through the adoption of a longer-term research strategy than is normally facilitated under most competitive funding arrangements.

UCD has recently established a 24ha long-term grassland experiment at Lyons Farm. The experiment consists of three sward types coupled with their appropriate nutrient input levels: perennial ryegrass monoculture with high N inputs (200 kg N ha⁻¹ yr⁻¹) (PRG), perennial ryegrass and white clover (PRGWC), a multi-species mixture containing three plant functional groups (grasses, legumes and herbs) (MS). A reduced nitrogen rate of 90 kg N ha⁻¹ yr⁻¹ will be applied to PRGWC and MS. Each sward type consists of four 2ha replicates which are hydrologically isolated and grazed under a calf to beef system at a stocking rate of 2.5 livestock units ha⁻¹ with animals originating from the nationally expanded dairy herd.

Through this research, UCD will make a significant contribution to enhancing the sustainability of grass-based production systems, by providing improved understanding of the key role of sward diversity in facilitating the development of low input, high output beef systems which deliver multiple ecosystem benefits. Here we will discuss our experience establishing this large and ambitious experiment, which is a site within the Global Farm Platform.

[35] THE ASSOCIATIONS OF MAJOR FOODS AND FIBRE WITH RISK OF ISCHAEMIC AND HAEMORRHAGIC STROKE: A PROSPECTIVE STUDY OF 418,329 PARTICIPANTS IN THE EPIC COHORT

Tammy Y.N. Tong, Paul N. Appleby, Timothy J. Key, Aurora Perez-Cornago on behalf of the EPIC-CVD Consortium

Cancer Epidemiology Unit, Nuffield Department of Population Health, University of Oxford

Background: The evidence of associations between individual foods and dietary fibre with subtypes of stroke (ischaemic and haemorrhagic) is not conclusive. We aimed to investigate this in a large prospective cohort.

Materials and methods: We analysed data on 418,329 men and women from nine European countries, collected over an average of 12.7 years of follow-up. Diet was assessed using validated country-specific questionnaires, calibrated using 24-hour recalls. Multivariable adjusted Cox regressions were used to estimate hazard ratios for ischaemic and haemorrhagic stroke associated with consumption of red and processed meat, poultry, fish, dairy, eggs, cereals, fruit and vegetables, legumes, nuts and seeds, and dietary fibre.

Results: Over an average of 12.7 years of follow-up, we observed 4281 cases of ischaemic stroke and 1430 cases of haemorrhagic stroke. For ischaemic stroke, lower risks were observed with higher consumption of fruit and vegetables combined (HR; 95% CI per 200g/d higher intake, 0.87; 0.82-0.93) and dietary fibre (per 10g/d, 0.77; 0.69-0.86) (p-trend<0.001 for both). Inverse associations were also observed for milk (per 200g/d, 0.95; 0.91-0.99, p-trend=0.02), yogurt (per 100g/d, 0.91; 0.85-0.97, p-trend=0.004) and cheese (per 30g/d, 0.88; 0.81-0.97, p-trend=0.008), while a positive association was observed with higher red meat consumption (per 50g/d, 1.14; 1.02-1.27, p-trend=0.02). For haemorrhagic stroke, higher risk was associated with higher egg consumption (per 20g/d, 1.25; 1.09-1.43, p-trend=0.002).

Conclusions: Risk of ischaemic stroke was inversely associated with consumption of fruit and vegetables, dietary fibre and dairy foods, and positively associated with red meat, while risk of haemorrhagic stroke was positively associated with egg consumption. The apparent differences in associations between ischaemic and haemorrhagic stroke highlight the importance of examining stroke subtypes separately.

[36] CONSUMER ATTITUDES TOWARDS ALTERNATIVE MEAT PRODUCTS: EXPECTATIONS ABOUT TASTE AND THE ROLE OF DISGUST

Yeliz Vural, Dani Ferriday and Peter J. Rogers

School of Psychological Science, University of Bristol

The demand for meat protein is of increasing concern level as the livestock sector contributes 18% of green-house gas emissions alone (FAO, 2006). Potential environmental and health benefits of meat alternatives have been in focus recently (Paris Agreement, 2015). However, there is relatively little scientific evidence regarding consumer expectations towards these products and the role of food disgust as a potential barrier (Verbeke et al., 2015). Therefore, this online study aims to explore what consumers expect from the taste of meat substitutes (cultured meat and plant-based 'meat') and how disgust might play a role in acceptance of these products. 200 participants, currently living in

the United Kingdom, will be randomly allocated to the four quadrants of a balanced design. Each participant will be presented twelve pictures, in total, of a range of alternative meat products and other food products (dairy and low-calorie products) with slightly different appearance and asked to rate the product according to expected pleasantness/fullness/satisfaction, willingness to pay for the product and disgust. This study will provide a rich insight into factors underpinning acceptance of meat replacements and can be expected to contribute the development of appropriate interventions to reduce meat consumption.

[37] ASSESSMENT OF SPATIAL, ENVIRONMENTAL, AND MANAGEMENT EFFECTS ON LAMENESS PREVALENCE IN UK SHEEP FLOCKS

Jessica Witt
University of Warwick

Footrot is an infectious disease of sheep, caused by *Dichelobacter nodosus*, that causes ~70% of all lameness in UK flocks and has significant economic and welfare implications. Some environmental factors have been implicated in the survival and spread of *D. nodosus*, including air temperature, rainfall, soil moisture, and soil type. These factors have effects, both individually and synergistically, on bacterial survival in the environment and establishment of disease. Environmental changes produce seasonal patterns of infection, but a model of this pattern within the UK does not yet exist.

The current work assesses the impact of several factors, including lameness management practices and static environmental conditions (e.g. soil composition) on the prevalence of lameness in 802 English flocks across two study periods (2012-2013 and 2013-2014) in a multi-level, multivariable negative binomial regression model. A Local Moran's I statistic was calculated to evaluate spatial autocorrelation of the dependent variable and the model residuals at the farm level. Management practices that were included in the negative binomial model were assessed for spatial patterns at the county level using the Getis-Ord G_i^* statistic to identify hot/cold spots of practice compliance.

Spatial clustering with some outliers was observed in the Local Moran's I results of the dependent variable. The model residuals showed no clustering, but several outliers were still present suggesting that some spatial variation was still not accounted for in the model. Evaluation of the Getis-Ord G_i^* results is currently underway, but initial impressions suggest there are variations in application of lameness management practices between counties.

[38] ASSESSING THE EU FOOD SYSTEM AND INNOVATION OPTIONS FOR THE LIVESTOCK SECTOR - THE SUSFANS PROJECT AND ITS FINDINGS

Monika Zurek¹ and Hannah van Zanten²

1 Environmental Change Institute, University of Oxford

2 Wageningen University, NL

Food systems around the world will have to transform to achieve what has been recently coined 'Sustainable Food and Nutrition Security'. For the EU food system this means that its various actors are interested in a number of specific outcomes, namely balanced and sufficient diets for EU citizens, reduced environmental impacts, viable agri-food businesses, and equitable outcomes and conditions of food system actors. The H2020 research project SUSFANS (Metrics, models and foresight for sustainable food and nutrition security in the EU, www.susfans.org) has assessed the performance of the EU food system across these outcomes, and created foresight on future food production, diets and sustainability impacts across these four societal goals. The project also investigated various innovation options for the EU food systems and their impacts on the food system outcomes. For this the project created a participatory process to map the food system actors and develop a set of performance metrics to assess and visualize system's performance and possible trade-offs associated with innovation options for food system transformation. The interactive SUSFANS Visualizer gives insights into the sustainability performance of European diets and food systems for the years 2010 to 2050. In this way one can compare the impact of strategies and policies and adjust these as needed. In the livestock sector the team specifically investigated options that can be mapped onto three different paradigms for change. These are the 'production narrative' ('producing more with less'), the 'consumption narrative' ('Eat less meat, none or less and better meat') and the 'circular narrative' ('Animals are essential for resource-efficient food production and we should avoid the feed-food competition by using waste streams and areas with low suitability for crop production'). All three narratives relate to each other and could be combined for finding a set of solutions across different EU member states.