Outcome and recommendations from the BBSRC cross-institute workshop on "The future role of livestock in food production" – Nov 11-12th 2019, The Roslin Institute, UK

Consolidated document from representatives from The Roslin Institute & affiliated organisations (The Global Academy of Agriculture and Food Security of the University of Edinburgh, Scotland's Rural College SRUC), the Pirbright Institute, Rothamstead Research Institute, and the Institute of Biological, Environmental and Rural Sciences (IBERS).[1]

A) Workshop remit and aims

The aim of this workshop was to bring together scientists (primarily from BBSRC-sponsored Institutes and affiliated organisations, but also relevant international experts), representatives from the livestock and food production industry, as well as funders and policy makers to:

1. Critically review existing evidence with respect to current threats and challenges from and for livestock production,
2. Identify priority areas for research to address these challenges and support sustainable livestock production, and to enable evidence-based policy making.

The workshop adopted the broad definition of the term livestock including all farmed animal species, i.e. including aquatic species and poultry. The workshop consisted of invited talks from 22 leading UK and international experts including academic scientists and representatives from the livestock breeding, farming and retail industry. These were followed by panel discussions and a closing statement by the BBSRC representative Kirsty Dougal (see programme in section E). Given the wide interest in this topic, registered participants had to be capped to 90 delegates.

Day 1 provided an evidence-based review of the diverse **Drivers of change in the role of livestock in sustainable agricultural systems for food production.**

Day 2 focused on **Research and innovation to define and support sustainable livestock production in future food systems,** considering in particular breeding, animal health, welfare and nutrition and enabling technologies.

B) Workshop outcomes

1. Evidence and knowledge gaps needed for robust policy making to shape the future of livestock production

[1] See last page for the full list of representatives that contributed to this document

1. There is strong quantifiable evidence that livestock production has a significant environmental footprint globally, and a general acceptance across workshop presenters and panellists that current livestock production systems must undergo substantial changes to better quantify and lessen this footprint. Business as usual is not an option, and indeed there are signs already that the field is adapting to environmental and social drivers.
2. Presented evidence suggests (e.g. pilot studies e.g. at the BBSRC-funded North Wyke Farm Platform, agricultural systems models and reviews of alternative protein sources) that full substitution of animal-based proteins by plant-based and alternative protein sources is not a feasible solution for meeting global nutritional demands within the near future. Reasons include availability of arable land, technical difficulties in generating high quantities of protein *in-vitro* at feasible economic and environmental costs, or potential negative side effects on human health and soil fertility associated with removal of livestock systems.
3. All evidence presented at the workshop pointed towards the expectation that livestock can and should continue to play an important, though possibly reduced role in providing nutritious food, including key micronutrients to the growing world population, within planetary constraints. Globally, demand for animal-source proteins have risen over the last 30 years and are expected to continue to rise (e.g. FAO statistics, IPCC report). Trends and demands differ between high income countries (HICs), where demand is stagnating, and Low and Medium Income Countries (LMICs), where livestock production is expected to play a greater role in reducing hunger, poverty and malnutrition. Development of strategies and policies should differentiate between geographical areas and livestock species (e.g. red meat vs poultry or fish).
4. Convincing quantifiable evidence was presented for all livestock species that substantial improvements in efficiency of production has been delivered in developed economies over the last 50 years. This is due to innovations in breeding, vaccines and treatments for infectious diseases, nutrition, husbandry and management, and implementation of bio-technologies. These improvements have led to significant reductions in GHG emissions and other pollutants, in resource and land use per unit product produced, and in some cases to simultaneous improvement of animal health and welfare. Importantly, it is expected that implementation of novel technologies (e.g. genomics, smart farming technologies) will lead to substantial further improvements in these traits. There was a strong consensus amongst workshop presenters / participants that the public and policy makers may not have been made fully aware of the power of existing and future innovations, thus hindering their swift uptake into practice (e.g. no livestock geneticist on the IPCC or other relevant panels).
5. Improvements have mostly taken place in high income countries (HICs), whereas Low and Medium Income Countries (LMICs) lag badly behind in research, innovation and implementation of new technologies. LMICs may require different solutions adapted to their specific climatic, environmental and

societal conditions. For example, the need to increase adaptive capacity and resilience as a priority relative to mitigating GHG emissions.

6. Refined quantitative assessments of the environmental footprint of livestock are required as
    - data used in some calculations referred to sub-optimal metrics (e.g. only the recent global warming potential GWP approach includes atmospheric half-lives in the assessment) or outdated systems; recent progress in production efficiencies (see point 4 above) and anticipated trends are often not properly taken into account due to lack of available recent data.
    - some current assessments lack sufficient differentiation between different farmed animal species, different animal production systems, variations within the systems, and also different countries, in particular HIC vs LMIC.
    - limitations in life-cycle-assessments often do not properly address the feed-food competition or interlinkages in the food system (e.g. circular usage of by-products to minimise food loss and waste and other externalities associated with different agricultural systems).
    - Externalities of livestock production, i.e. negative and sometimes positive side-effects that arise from production and consumption but which are not priced by the market such as destruction of natural habitats, loss in biodiversity, or positive or negative effects on human and animal health and welfare, are currently still poorly quantified.
7. Compared to the established systems of land-based livestock species, aquaculture is undergoing fundamental changes with rapid transition towards well-managed selective breeding programmes for many aquaculture species. Many of these species are still in the early-stages of domestication, and have very high fecundity, and as such there is much scope for genetic improvement in aquatic species.
8. Infectious diseases remain a significant threat to animal production and welfare, and will continue to require innovative solutions to prevent, detect and treat them as pathogens evolve. Moreover, it was recognised that livestock can be reservoirs of zoonotic pathogens that affect the human population, and that antibiotic use in farm animals (both for treatment of bacterial diseases and as growth-promoters) has the potential to blunt the effectiveness of human medicines. Present scientific understanding is insufficient to achieve the goal of eradication or control of key animal and zoonotic pathogens.
9. Livestock production is much more than production of meat or consumable proteins. Many other aspects such as the role of farmed animals for shaping societies, livelihood of rural communities, tourism and also One Health including crucially emergence of antimicrobial resistance and soil health need to be considered when defining the future role of livestock (See point 6 above, wrt externalities of livestock systems).
10. Alternative protein sources (e.g. insects, cultured meat) directly for human consumption or as animal feed could potentially play an important part in defining the future role of farmed animals in food production - e.g. as potential

substitutes. More research into e.g. their nutritional value, environmental footprint, and impact on animal or human health is required.

2. Identified data and research needs towards effective research programmes to shape the future role of farmed animals

In line with the workshop programme, identified data and research needs are broadly categorized into (a) those that help to define and optimise the role of livestock within the entire food production and ecosystem, i.e. 'whole systems wide and (b) those that focus on improvement within the livestock sector, i.e. 'livestock specific. Clearly, both categories are interlinked, and future research programmes and strategies should tackle priorities in both categories simultaneously. In particular, greater interdisciplinary thinking within the research community (in particular between biological, mathematical & computational and social sciences) is required, and more initiatives to establish interdisciplinary challenge-driven research programmes should be launched.

2.1 Whole systems-wide: Position of livestock in the entire food production and eco-system:

a) Development of appropriate and unified metrics to quantify the real environmental footprint of livestock production systems and other externalities (e.g. loss in biodiversity, human & animal health and welfare), as well as reductions associated with changes to the system. These metrics should take all aspects (including required inputs, waste and outputs) of the production system into account.
b) Improved life-cycle assessment methods and predictive systems models that include relevant inter-linkages and circularities between various food-systems components and also better incorporate underlying sources contributing to the large existing variation within and between the different livestock production systems.
c) Identification of data requirements and development of infrastructure for generating the data required to calibrate the systems models.
d) Development of an effective monitoring framework for sustainable livestock and food production systems to enable precision farming and disease forecasting and mitigation.
e) Studies into improved understanding of the role of farmed animals as reservoirs of zoonotic pathogens and drug resistances that can affect the human population.
f) Better integration of social science with biological sciences to better understand and mitigate societal, political and economic barriers that may hinder uptake of new solutions into practice.
g) Evidence based reviews and predictive models to evaluate the potential contribution of science and innovation to sustainable global food production.
h) There is a continuing need for research capacity building and programmes in LMICs interlinked with those in HICs that will facilitate the development of

systems adapted to different geographical, climate and economic environments.

2.2. Livestock specific: Research priorities to achieve improvements within the livestock production sector.

Animal Health, Welfare and nutrition:

i) Comprehensive 'economic' models that can calculate the combined economic and environmental costs and other externalities associated with livestock disease and poor welfare and of the benefits associated with reduction in disease incidence and improvement in welfare. These will facilitate more target-led approaches to address the current threats to livestock production.
j) Improved surveillance and data-supported prediction models for disease forecasting and spread that implement genomic information and newly emerging tools for disease monitoring and diagnostics.
k) Development of effective research and tools (e.g. bio-imaging, diagnostics, models) to provide essential understanding of host-pathogen interactions in transmission dynamics and co-evolution, and effect of disease control methods (e.g. vaccines, genomic selection) on these.
l) More research into novel feed sources (e.g. insects, algae as animal feed) including impact on production and health traits, and environmental pollutants, as well as economic values and other externalities associated with a shift to these feed sources.
m) Defining optimal grazing systems (swards and strategies) to deliver animal performance, biodiversity, soil health and reduce competition with human edible resources.
n) Research into alternatives to antibiotics in animal production, such as e.g. novel vaccines and animals selected or edited for resistance to disease. Paucity of basic knowledge and tools to study the immune systems of farmed animals (and some pathogens) significantly constrains progress.

Animal breeding and Innovative Technologies:

o) Use of genomics to obtain a better understanding of natural genetic diversity and evolutionary processes of livestock, pathogens and microbiomes.
p) Methods for effective integration of genomics, smart technologies and new phenotypes into genetic evaluations and breeding programmes that increase production as well as health and welfare with lower environmental footprint.
q) Research into influencing genetic and environmental factors and appropriate prediction models underlying resilience of individual animals and whole farming and production systems.

r) Research into the genetic basis of resilience and disease resistance traits, to harness host genetic variation to reduce the threat and impact of pathogens and other environmental stressor on farmed animal populations.
s) Further development and implementation of next generation phenotyping technologies for real-time monitoring and the necessary data infrastructure and processing pipeline for effective translation of data into knowledge and decision making.
t) Identification of gene editing methods and targets, integration of gene editing into breeding programmes, and assessment of the consequences of genome editing on animal production, health and environmental footprint.
u) Development and testing of technologies that allow direct selection for lower greenhouse gas emissions.
v) Integration of social science to address societal, political and economic concerns earlier in the research and development process, including the setting of general goals.

3. Required changes in funding structures and regulatory systems

The workshop emphasized the immediate urgency for transformative research and innovation in livestock and food production systems to respond to the current major and pressing challenges raised by the climate emergency. The panel discussions highlighted that this requires not only a shift in interdisciplinary thinking by the research community, but also a shift of UKRI's funding model towards long-term and challenge-driven funding streams. Compared to response mode projects with long-term implementation plan, or spontaneous funding calls for small-scale short-term projects, these larger challenge-driven programmes hold greater promise in achieving the required substantial change in planetary food production systems. As pointed out by the BBSRC representative Kirsty Dougal during the meeting, the current UKRI shared common funds (e.g. SPF, FIC, ISFC, strategic Lola) for large-scale interdisciplinary approaches to grand challenges already demonstrate the shift in funding structure. However, future schemes should incorporate a stronger focus on livestock research in order to optimise the role of livestock in future sustainable food production. The following specific suggestions were brought forward:

a) A transparent long-term research, innovation and investment strategy and action plan aligned with government policies and strategies. Different strategies may be required for LMICs and HICs and different livestock systems. It is also important to consider both the national and international consequences of UK funding for livestock research to avoid e.g. UK losing the forefront on livestock science and the international export market, and import of livestock produced in less efficient systems with greater environmental footprint.
b) Investment in large-scale multidisciplinary strategic research programmes to design and innovative farming systems addressing the global climate and food emergency. This may require substantial restructuring / expansion of current institutions and increased ISP funds with >5 year secure funding to deliver strategic outcomes to grand challenges (alongside competitive grants).

c) More specific research calls related to the development of sustainable, resilient livestock and food production systems that can face current and future threats and meet new emission, health and welfare, and production targets. Funded projects should be target-driven with quantifiable estimates of their contribution to improving the food systems.
d) A funding system that fosters a more rapid and smooth pipeline from research to practice (typical time-scale from e.g. response mode proposal to implementation can be decades). This highlights the continued importance of leveraging schemes such as LINK, IPA, or Innovate UK to stimulate joint research with clear path to implementation. National Agri-Tech centres formed to address these challenges, require recurrent funding to sustain them. A revision of current project evaluation criteria may be required to achieve the appropriate balance between highly ambitious, early stage blue sky research and mid-to-late-stage research that facilitates implementation into practice. There was a common consensus amongst workshop participants that uptake of research into practice is often hindered by lack of funding for intermediate steps ("death valley") in the development-implementation pipeline.
e) It is paramount that livestock researchers, industry and funding bodies contribute to the development of fit-for-purpose regulatory frameworks for implementation of innovative research solutions. This is particularly relevant for contested technologies such as genome editing and also infectious disease surveillance and control. The UK research programmes and regulatory frameworks need to fit with EU frameworks, e.g. links to EU Green Deal research programmes would make sense.
f) UKRI may consider re-routing some of the money saved from the UK's current contribution to EU research budgets to establish the necessary large strategic research programmes and associated bio-science capacities and training programmes.

4. Related documents and further anticipated outcomes of the workshop

- A position paper on "The future role of farmed animals in food production" for publication in a high profile scientific journal is currently under development. This accompanying paper will also include the scientific references to back up the scientific evidence presented at the workshop and summarized here.
- Animal Task Force publication "Why is European animal production important today? Facts and figures http://animaltaskforce.eu/Portals/0/ATF/Downloads/Facts%20and%20figures%20sustainable%20and%20competitive%20livestock%20sector%20in%20EU_FINAL.pdf
- Document for the previous BBSRC cross-institute workshop at The Roslin Institute on Precision Breeding: https://docs.google.com/document/d/14iU0S6m2vXnPWmyoDioF9cj7tD6EsHeqEUDgaGSk7IQ/edit?usp=sharing

C) Overall summary and conclusion

The overall consensus of the workshop was that livestock production, including aquaculture, will and should continue to be part of the solution to meet the nutritional demands of current and future generations within planetary constraints, as well as deliver other critical services (soil health, biodiversity, supporting rural communities, optimising waste streams etc.). However, this requires innovative transformative research together with changes in funding structures and new routes of implementation as outlined in section B above.

D) Contributing Authors

The following representatives of BBSRC Institutes and affiliated organisations contributed actively to the document (listed according to affiliation):

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We would like to thank the BBSRC representative Kirsty Dougal for constructive comments to an earlier draft.

E) Workshop Programme

BBSRC Cross-Institute Workshop: The future role of livestock in food production

November 11-12th 2019, The Roslin Institute

Programme

Day 1: Drivers of change in the role of livestock in food production for sustainable agricultural systems

11.45pm	**Registration and Lunch**
12.30pm	**Welcome and Introduction** (A. Doeschl-Wilson)
12.45pm	**Session 1: Drivers of change – part 1** (chair Helen Sang)
12.45pm	Phil Thornton (ILRI) - The current and future role of livestock in global food production
1.15 pm	Alison van Eenenaam (UC Davis) – The importance of Innovation to the Sustainability of Animal Agriculture
1.45 pm	Imke de Boer (Wageningen University) – The role of animals in future food systems
2.15pm	Maggie Gill (Univ. of Aberdeen) – Impact of climate change and Environmental footprint / policies
2.45 pm:	**Group photo & Coffee Break**
3.15 pm	**Session 1 cont.: Drivers for change – part 2** (chair Geoff Simm)
3.15 pm	Simon Gubbins (Pirbright): Emerging diseases
3.40 pm	Nigel Miller (Scottish Indep. Inquiry on Food, farming and climate / NFU): Farmers perspective
4.05 pm	Chris Brown (ASDA): Consumer perspective
4.30 pm	Michael Lee (Rothamsted): The role of grazing livestock in sustainable food production – for human and planetary health
4.55 pm	Dominic Moran (Global Academy): Addressing externalities from livestock production and consumption
5.20 pm:	Panel discussion (chair Geoff Simm): Evidence (& gaps) synthesis of key drivers for change in livestock and food production
5.45 pm	**Drink reception and poster session**
7.30 pm	Dinner for invited speakers (collection 7pm)

Day 2: Defining and achieving the future role of livestock in future food production

8.45 am	**Session 2: Breeding for the future** (chair Kellie Watson)
8.45 am	Marco Winters (AHDB) – Cattle breeding
9.10 am	Andreas Kranis (Aviagen)– Poultry breeding
9.35 am	Pieter Knap (Genus / PIC) – Pig breeding
10.00 am	John Benzie (Worldfish) - The future of fish in food production
10.25 am	Panel discussion (chair: Kelly Watson): Breeding for the future
10.50 am	**Coffee Break**
11.15 am	**Session 3: Animal health and welfare & Nutrition** (chair Simon Gubbins)
11.15 am	Don King (Pirbright): New tools and approaches to estimate the endemic burden of infectious disease in livestock
11.35 am	Andrea Doeschl-Wilson (RI): Towards a more integrative infectious disease control
11.55 pm	Jon Moorby (IBERS): Feeding and breeding for productive, healthy and efficient livestock
12.15 pm	Cathy Dwyer (SRUC): Incorporating animal welfare into sustainable livestock
12.35	**Lunch**
1.30 pm	**Session 4: Enabling technologies** (chair Ross Houston)
1.30 pm	Marianne Ellis (Univ. Bath): Cultured meat as an alternative protein source
1.55 pm:	Wilfried Haerty (Earlham): Characterization of regulatory elements and impact of mutations within them
2.15 pm	Mark Pallen (Quadram): The role of the microbiome in future livestock production
2.35 pm	John Hickey (RI): Integrative breeding
2.50 pm	**Coffee**
3.20 pm	Helen Sang (RI) (TBC): Genome editing
3.40 pm	Graham Plastow (University of Alberta): Smart Technologies to deliver precision livestock agriculture
4.10 pm	Panel discussion (chair Ross Houston): Future direction for livestock science: Identifying research and resource needs
4.45pm	Kirsty Dougal (BBSRC): BBSRC funding streams and concluding remarks
5.00 pm	Sojourn