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Animal Production Science

Supplementary Material

Perspective on scientific truth versus scientific evidence; maintaining integrity in global food systems

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Re: Evaluation of the footnote material of the three 2-pager documents for solution cluster sustainable livestock at the UN Food Systems Summit proceedings:

Sustainable Livestock C – Aligning Production to Consumption

Sustainable Livestock B – Grazing for Soil, Climate and People

Sustainable Livestock A – Scaling Best Practices and Technology

By: Members of the Scientific Council of World Farmers Organization (SC-WFO)

On: xxx August 2021

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Note to the layout and process of evaluation.

The italic bold statement is copied from the 2-pager documents created by the respective focal points. The statement is preceded by the footnotes numbers (FN) that are references for this statement. The FN source is listed below the statement. Comment and evaluation by SC-WFO is provided below the source in indented text. The sources are evaluated and commented on with the following descriptions:

1.) Correct: this source is an adequate reference to the statement
2.) No relevance/wrong source: when the source has no relevance to the statement
3.) Proof not provided: when the source does not provide a proof for the statement
4.) Weak methodology in a scientific journal article: when the scientific source employs weak or inappropriate methodology that are easily revealed as severely biased

Sources may also have several of the three shortcoming characteristics.

The sources might refer to scientific journal articles, public policy documents or industry and company case examples of successful practices.

The first eight footnotes were not evaluated as they are the sources for the initial paragraph which is identical in each of the three C, B and A 2-pager documents.

An example for a wrong source is for instance when the FN 15 of the C-paper refers to a large-scale scientific joint review work by EMA and EFSA as support of the statement that reduction of meat and dairy products is necessary to reduce the use of antimicrobials. However, the review by EMA/EFSA does not mention meat and dairy reduction, let alone as a solution towards AMR.

An example for a proof not being provided, is where FN 43 of the C-paper is cited as support that animal production led to overuse and pollution of water. However, FN 43 calculates the water footprint of various foodstuffs, including animal source foods. It does not define which of these water footprints might be an “overusage”, which requires a different analysis.

An example for weak methodology is FN 38 of the C-paper, which calculates embedded feed calories in livestock products and then supports the statement that a poor conversion ratio of feed calories into livestock food calories is a threat to food security. Such an analysis makes no allowance for the quality of the food produced in terms of proteins, minerals, vitamins and trace elements.

In summary:

Sustainable Livestock C – Aligning Production to Consumption

In total, out of 53 sources provided for the two pages of text of the C paper (besides the first 8 which were common to each of the three papers, and including multiple shortcomings):

- 11 sources are correctly attributed
- 17 sources are wrong or irrelevant and thus the statement is unsupported
- 22 sources are relevant to the statement, but do not support the statement. (Often the source says the opposite of the statement)
- 18 sources employ weak methodologies

Sustainable Livestock B – Grazing for Soil, Climate and People

In total, out of 56 sources provided for the two pages of text of the B paper (besides the first 8 which were common to each of the three papers:

- 53 sources are correctly attributed
- 1 source is wrong or irrelevant and thus the statement is unsupported
- 2 sources are relevant to the statement, but do not support the statement

Sustainable Livestock A – Scaling Best Practices and Technology

In total, out of 45 sources provided for the two pages of text of the A paper (besides the first 8 which were common to each of the three papers:

- 42 sources are correctly attributed
- 3 sources are relevant to the statement, but do not support the statement

Rome, xxx August 2021

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The evaluation in detail for paper Sustainable Livestock C – Aligning Production to Consumption

FN 9,10,11,12: ***The solutions are proposed in the context of a scientific evidence-base showing that a significant reduction in global consumption of meat and dairy is needed if we are to achieve the Sustainable Development Goals and to meet the Paris climate targets [9,10,11,12]***

Source FN 9: Springmann, M., Clark, M., Mason-D'Croz, D. *et al.* Options for keeping the food system within environmental limits. *Nature* **562,** 519–525 (2018)

Comment by SC-WFO: proof not provided; weak methodology

The conclusion of this source says: *"Our analysis suggests that staying within the planetary boundaries of the food system requires a combination of measures: GHG emissions cannot be sufficiently mitigated without dietary changes towards more plant-based diets…."* In the Extended Data Table 1 of this source, the authors specify that such dietary changes would mean restriction to maximum intakes for red meat of three 100 g servings per week, ie 43 grams per person per day on average.

According to the Global Burden of Disease (GBD) collaborators, the median intake of red meat among the high consuming populations in the world is already in the region of just around 50 grams per day. The global average is below 20 grams per day. Thus, a significant reduction from the current levels as of GBD does not seem to be necessary in order to meet the desired dietary composition of the authors for this source, and therefore this source does not provide proof for "*need of significant reductions*".

Secondly, we note that the authors seemed to have made all their climate-relevant calculations in CO2 equivalents. This is methodologically not correct for enteric methane emissions of cattle for beef and dairy, since the geochemical warming dynamics of the planetary boundary of earth surface warming functions differently in case of methane compared to carbon dioxide. The source is therefore methodologically not fit for purpose for the above statement on meeting Paris climate targets.

Source FN 10: Bajželj B., Richards K.S., Allwood J.M., Smith P., Dennis J.S., Curmi E. & Gilligan C.A. (2014), Importance of food-demand management for climate mitigation. Nature Climate Change, Vol 4, October 2014.

Comment by SC-WFO: weak methodology

The Bajzeli 2014 source is principally of much higher methodological quality than Springmann 2018 quoted above. However, there are nonetheless some fundamental flaws incorporated in it. Its underlying logic ultimately implies that if less feed for animals was grown in the high productivity agricultural regions of the world, ie Europe and the Americas, then these land areas could be diverted for human food production for providing for the expanding population in Africa and Asia (the scenario also includes assumptions about yield gap closures which however are not relevant here). The flaw in this thinking is that the model does not include trade and balance of payment conditions between the Global North and the Global South. Bajzeli's model assumes that the Global North would be exporting agricultural goods to the

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Global South on a scale which would be unaffordable to the Global South. Therefore, in conclusion, this paper cannot prove how a reduction of consumption of meat and dairy, which would primarily occur in the Global North, can contribute to meet the Paris climate targets and the SDG's, because under this scenario the Global South would experience widespread starvation and malnutrition and the SDG's would be missed by large margin.

Source FN 11: Springmann M., Godfray H.C., Rayner M. & Scarborough P., 2016. Analysis and valuation of the health and climate change co-benefits of dietary change. PNAS vol. 113 no. 15: 4146–4151

Comment by SC-WFO: proof not provided; weak methodology

This source neither provides primary nor modelling evidence for the need to significantly reduce global consumption of meat and dairy. As the title implies, this source is an economic valuation, not a geophysical modelling of the global food system, and is therefore incapable of providing evidence for the above statement.

Secondly, this source betrays signs of scientific insincerity. Springmann et al 2016 refers to the Global Burden of Disease Study 2010, by writing: *"Given the availability of consistent epidemiological data, we focused on changes in the consumption of red meat, and of fruits and vegetables, which together accounted for more than half of diet related deaths in 2010…."* However, in the referenced GBD 2010 study, red meat consumption was proven to be the least important out of 43 risk factors, and was so unimportant that the GBD authors did not even show the loss of disability-adjusted life years for red meat consumption. Lumping this essentially non-data-point together with the dietary risk factors of diets low in fruits and vegetables, then claiming for this combination to be more than 50% of all diet related deaths (the real numbers are 39% for diet low in fruits, 14% for diet low in vegetables, and 0.3% for diet high in red meat out of all dietary risk factors in GBD 2010) is insidious. Further on in the actual calculations, the authors employ various statistical maneuvers with sources that are strongly biased against meat products. In this way, Springmann et al increased the statistically insignificant global mortality from red meat consumption of 38,092 deaths in GBD 2010 to their own modelling projection of 8.1 million deaths that could be avoided per year by shifting to a "vegan diet". By most definitions known to us, such handling defies scientific propriety, and would disqualify Springmann et al as acceptable sources for public policy making.

Source FN 12: Clark et al, 2020. Global food system emissions could preclude achieving the 1.5° and 2°C climate change targets. Science 370, 705–708

Comment by SC-WFO: weak methodology

This source has been authored by the same team at Oxford Martin School and Univ of Minnesota as the above source FN 11. Its scientific credentials could therefore be considered just as disqualified as that source FN 11. Specifically in this source, the authors aim for a sensationalist outcome by modeling the outcomes of an extrapolation of current trends of GHG emissions in the global food system. However, both the trends chosen and the measurement methodologies applied are heavily selection-biased against livestock. Therefore, the outcome is a circular argument: feeding a model with biased data will create the desired biased outcome.

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FN 13: ***The solutions are proposed in the context of a scientific evidence-base showing that a significant reduction in global consumption of meat and dairy is needed if we are….to reduce the environmental harms and overuse of natural resources stemming from current livestock production [13]…***

Source FN 13: Schader C et al. 2015. Impacts of feeding less food-competing feedstuffs to livestock on global food system sustainability. J. R. Soc. Interface 12: 20150891.

Comment by SC-WFO: weak methodology; proof not provided

This source suffers from the same shortcoming as the above source FN 10. It makes assumptions about a desired global distribution of food production in order to be sustainable, that are unrealistic given its implied global balance of payment and trade situation of the Global North and the Global South. Implementation of such a scenario would likely lead to mass starvation and malnutrition in the Global South countries.

Regardless of the macroeconomic impossibility of this scenario, the source does not purport to prove the point that it is "*needed"* to reduce global consumption of meat and dairy to reduce environmental harms. The analysis in this source models a "*possibility"* of how environmental impacts could be minimized in a future food system scenario, but does not make claims as to "*necessity"*.

FN 14: ***The solutions are proposed in the context of a scientific evidence-base showing that a significant reduction in global consumption of meat and dairy is needed if we are….to lower the incidence of non-communicable disease, [14]***

Source FN 14: Willett et al, 2019. Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems

Comment by SC-WFO: weak methodology; proof not provided

This source is the so-called EAT Lancet diet which has been discredited by the global scientific community, so much so that even the WHO withdrew its initial support from it. The EAT Lancet diet has been shown by numerous scientists to be among other things, agronomically infeasible (for instance global nuts production needs to increase 20x), upper middle class-biased (the diet shopping list includes tahini, olive oil and sushi sheets), nutritionally redoubtable (called by one globally renowned public health expert to be science fiction), unaffordable to most of the global population (see below reference FN 24) and by own admission of EAT's science director was not set due to environmental considerations despite its corresponding claims. More details on the overview of the criticisms to the EAT Lancet diet can be found at https://aleph-2020.blogspot.com/2020/10/towards-great-food-transformation.html

Regarding the concrete claim here, no firm evidence was provided by the authoring consortium of the EAT Lancet diet, why a reduction in global consumption of meat and dairy will lower the incidence of non-communicable disease on a noticeable scale.

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FN 15: ***The solutions are proposed in the context of a scientific evidence-base showing that a significant reduction in global consumption of meat and dairy is needed….to minimise the use of antimicrobials [15]***

Source FN 15: EMA (European Medicines Agency) and EFSA (European Food Safety Authority), 2017. EMA and EFSA Joint Scientific Opinion on measures to reduce the need to use antimicrobial agents in animal husbandry in the European Union, and the resulting impacts on food safety

Comment by SC-WHO: No relevance/wrong source

This 245-page EMA / EFSA joint scientific opinion neither mentions nor implies with a single word that the use of antimicrobials would be minimized by a reduction in global consumption of meat and dairy, let alone a significant reduction. The reference is not relevant to the statement. For the avoidance of doubt, here is what this source actually says in its summary: *"To minimise antimicrobial use, a multifaceted integrated approach should be implemented, adapted to local circumstances. Recommended options (non-prioritised) include: development of national strategies; harmonized systems for monitoring antimicrobial use and AMR development; establishing national targets for´antimicrobial use reduction; use of on-farm health plans; increasing the responsibility of veterinarians for antimicrobial prescribing; training, education and raising public awareness; increasing the availability of rapid and reliable diagnostics; improving husbandry and management procedures for disease prevention and control; rethinking livestock production systems to reduce inherent disease risk."*

FN 16: ***The solutions are proposed in the context of a scientific evidence-base showing that a significant reduction in global consumption of meat and dairy is needed….to minimise…the risk of the emergence of zoonotic disease [16]***

Source FN 16: UNEP & ILRI, 2020. Preventing the next pandemic

Comment by SC-WHO: No relevance/wrong source

This UNEP report neither mentions nor implies with a single word that the risk of emergence of zoonotic disease would be minimized by a reduction in global consumption of meat and dairy, let alone a significant reduction. The reference is not relevant to the statement.

FN 17: ***Research shows that the production of animal sourced foods needs to be reduced by at least half globally to stay within environmental limits and planetary boundaries [17]***

Source FN 17: Springmann *et al.* Options for keeping the food system within environmental limits. *Nature* **562,** 519–525 (2018).

Comment by SC-WFO: proof not provided; weak methodology

This is the same source as FN 9 for essentially the same redundant statement. FN9 was supposed to prove that significant reductions in meat and dairy are needed, whereas here a minimum reduction of 50% of animal sourced foods is postulated. FN9 was already not able to prove significant reductions, so it can also not prove at least 50% reduction as FN17. Moreover, the main authors are from the same Oxford team of FN 11 that are testing the limits of scientific propriety, and therefore would disqualify themselves from public policy making at any rate.

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FN 18, 19: ***The solution lies in more equitable distribution of global production and consumption levels within planetary boundaries [18, 19]***

Source FN 18: Willett et al, 2019. Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems

> **Comment by SC-WFO: weak methodology; no relevance/wrong source**
> This is the same EAT Lancet source as FN 14 and its methodology is no more appropriate for this statement than in FN 14. Additionally, this source is not concerned with an equitable distribution of global production and consumption; the word *"equitable"* is not mentioned once in the document. The reference is not relevant to the statement.

Source FN 19: EAT. Diets for a better future https://eatforum.org/content/uploads/2020/07/Diets-for-a-Better-Future_G20_National-Dietary-Guidelines.pdf

> **Comment by SC-WFO: weak methodology; proof not provided.**
> This source is not a scientific investigation, but a political position paper curated by the EAT initiative. Essentially it draws on the same sources as the EAT Lancet diet of FN 14 and FN 18, and therefore shares the same methodology shortcomings, and is therefore also not an independent separate scientific source.
>
> At least this source does expand the argumentation towards its propagated global solution being *"equitable"* and could therefore be considered a relevant source. However, even though this claim of *"equitable"* is made several times throughout the document, no evidence is provided or referenced, how such equity would be created. Beyond being claimed, the proof is therefore missing.

FN 20, 21, 22, 23: ***Overall global reduction in the consumption of animal source foods should be undertaken on a contraction and convergence basis. This would enable increased consumption of animal-sourced foods in some countries and regions and substantial reductions amongst high-consuming populations [20, 21, 22, 23]***

Source FN 20: Willett et al, 2019. Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems

> **Comment by SC-WFO: weak methodology; no relevance/wrong source**
> This is the same EAT Lancet source as FN 14 and FN 18 and its methodology is no more appropriate for this statement than in FN 14.
>
> Secondly, it is not clear what the text means with *"contraction and convergence"* and how this would enable increase there and reductions here. This source FN 14/18/20 does not illuminate a contraction and convergence concept. The word convergence is not mentioned in the source. The source does not appear to be relevant to the statement.
>
> Thirdly, it seems to be the third statement in a row saying the same thing with the same sources with only slightly different wording.

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Source FN 21: Clark et al, 2020. Global food system emissions could preclude achieving the 1.5° and 2°C climate change targets. Science 370, 705–708

Comment by SC-WFO: weak methodology; no relevance/wrong source
This is the same Oxford authors source as FN 12 and its methodology is no more appropriate for this statement than in FN 12.

Secondly, it is not clear what the text means with *"contraction and convergence"* and how this would enable increase there and reductions here. This source FN 12/21 does not illuminate a contraction and convergence concept.

Thirdly, it seems to be the third statement in a row saying the same thing with the same sources with only slightly different wording

Source FN 22: Springmann M., Godfray H.C., Rayner M. & Scarborough P., 2016. Analysis and valuation of the health and climate change co-benefits of dietary change. PNAS vol. 113 no. 15

Comment by SC-WFO: weak methodology; no relevance/wrong source
This is the same Oxford author's source as FN 11 and its methodology is no more appropriate for this statement than in FN 11.

Secondly, it is not clear what the text means with *"contraction and convergence"* and how this would enable increase there and reductions here. This source FN 11/ FN 22 does not illuminate a contraction and convergence concept, and does not use either word in its entire text.

Thirdly, it seems to be the third statement in a row saying the same thing with the same sources with only slightly different wording, and being as scientifically insincere as in FN 11.

Source FN 23: Keren Papier, Anika Knuppel, Nandana Syam, Susan A. Jebb & Tim J. Key (2021): Meat consumption and risk of ischemic heart disease: A systematic review and metaanalysis, Critical Reviews in Food Science and Nutrition, DOI: 10.1080/10408398.2021.1949575

Comment by SC-WFO: no relevance/wrong source;
This source neither mentions nor implies anything about contraction or convergence, nor increased consumption there versus reduction here. As the title says, it is a review of meat consumption and risk of ischemic heart disease. The reference is not relevant.

FN 24: ***Issues of affordability [24] would need to be addressed…***

Source FN 24: Hirvonen, K et al, Affordability of the EAT–Lancet reference diet: a global analysis, The Lancet, 2019. https://doi.org/10.1016/S2214-109X(19)30447-4

Comment by SC-WFO: correct source; (though proof not provided)
This is a remarkable source, because it demonstrates that the EAT Lancet diet is not affordable to a significant portion of the global population. It concludes: *"Our study showed that EAT–Lancet reference diets are not affordable for much of the world's low-income population. In the 26 countries (0·50 billion people) classified as low income by the World Bank, obtaining enough of the least expensive locally available items to meet EAT–Lancet targets would require 89·1% of the mean per capita household income. In the 47 countries (2·97 billion people) classified as*

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lower-middle income, these diets would cost 52·4% of the mean per capita household income." However, other than the text possibly implies, this source does not make suggestions how this affordability issue can be addressed. A solution is not provided. It is therefore not a source that can prove how affordability can be solved. However, the placing of this reference behind the word affordability, also strictly speaking does not claim that proof.

FN 25,26: ***The worrying disconnect between the retail price of food and the true cost of its production in terms of harms to the environment and human health amongst others [25 26]…needs to be addressed.***

Source FN 25: FAO, 2015. Natural capital impacts in agriculture
http://www.fao.org/fileadmin/templates/nr/sustainability_pathways/docs/2015-11-19_Natural_Capital_Impacts_in_Agriculture-Supporting_Better_Business_Descision-Making_v8.pdf

Comment by SC-WFO: correct source
No further comment

Source FN 26: Battini N, Parry I & Wingender P, 2020. IMF Working Paper. Climate Mitigation Policy in Denmark: A Prototype for Other Countries

Comment by SC-WFO: no relevance/wrong source; weak methodology
This source discusses carbon pricing schemes to reduce GHG emissions in the Danish transportation and agricultural sector. It is a priori a seemingly sensible review of existing policy in Denmark of how to integrate GHG-related cost externalities into production costs. It is not, however, an encompassing review and discussion of *"true cost of production in terms of harms to the environment and human health".* It is therefore not a suitable reference for this statement.

Secondly, the political intent of the source is revealed when on page 37 the source suddenly veers off course and describes a number of supposedly additional environmental and public health benefits that could be gained from a GHG emission mitigation strategy, notably them being a reduction in zoonotic diseases, antimicrobial resistance, non-communicable diseases and air and water pollution, and then for good measure adds some remarks on whaling. None of these sweeping statements are related or founded by the preceding methodological discussion on GHG emission mitigation through carbon pricing. The source thus reveals extremely weak methodology, and casts into doubt also the propriety of the carbon pricing discussion. As an IMF working paper, this source is also not subject to peer-review process. One also wonders why or how the IMF should be concerned with or be competent in matters of zoonotic diseases, AMR and NCD's.

FN 27, 28, 29, 30: ***This would not only reduce the harms to environment caused by excessive livestock production but deliver health benefits by reducing the incidence of heart disease, obesity, type 2 diabetes and certain cancers [27,28,29,30].***

Source FN 27: Friel S., Dangour A.D., Garnett T., Lock K., Chalabi Z., Roberts I., Butler A., Butler C.D. Waage J., McMichael A.J. and Haines A., 2009. Health and Climate Change 4: Public health benefits of strategies to reduce greenhouse-gas emissions: food and agriculture. Published online November 25

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Comment by SC-WFO: proof not provided; weak methodology
This source is neither an epidemiological nutritional investigation in how reduced livestock production might be related to delivering health benefits since it takes assumptions on this matter from other sources, nor does it prove how harms to the environment would be reduced since it only models GHG emissions. Moreover it models just two case studies, one for UK and for the city of Sao Paulo. The source also does not provide a definition of what counts as "*excessive*". This source is thus not able to support the sweeping global statements in the text.

Additionally, this source dates from the year 2009. In the meanwhile, it has been overtaken by plenty more up-to-date investigations both in nutrition and in GHG emission modelling, using better data and better modelling technologies. Its methodology is therefore weak, even if it had been applied to more than two case studies only.

Source FN 28: Aston LM, Smith JN and Powles JW, 2012. Impact of a reduced red and processed meat dietary pattern on disease risks and greenhouse gas emissions in the UK: a modelling study. BMJ Open Vol 2, Issue 5 http://bmjopen.bmj.com/content/2/5/e001072.full.pdf+html

Comment by SC-WFO: proof not provided; weak methodology
This source is neither an epidemiological nutritional investigation in how reduced livestock production might be related to delivering health benefits since it takes assumptions on this matter from other sources, nor does it prove how harms to the environment would be reduced since it only models GHG emissions. Moreover, it models just one case study, the UK. The source also does not provide a definition of what counts as *"excessive*". This source is thus not able to support the sweeping global statements in the text.

Additionally, this source dates from the year 2012. In the meanwhile, it has been overtaken by plenty more up-to-date investigations both in nutrition and in GHG emission modelling, using better data and better modelling technologies. Its methodology is therefore weak, even if it had been applied to more than one case studies only.

Source FN 29: Anand, S. et al., 2015. Food Consumption and its Impact on Cardiovascular Disease: Importance of Solutions Focused on the Globalized Food System. Journal of the American College of Cardiology, 66, no 14

Comment by SC-WFO: proof not provided
This source is a widely encompassing review of all the different ways in which diet choices may impact cardiovascular disease (CVD), ranging from refined carbohydrates to alcohol. Regarding livestock products, it could identify associations primarily with processed meats which represent only a modest share of all meat consumed, while stating that little evidence was available for unprocessed meats. The study entirely exonerated dairy and egg products from being related to CVD. Therefore, this source cannot support the sweeping statement that reduction of excessive livestock production would deliver health benefits, because first of all it does not define what is excessive, and secondly, at best health benefits of reduced CVD would be associated with processed meats, but not any other livestock product.

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Source FN 30: Bouvard et al, 2015. Carcinogenicity of consumption of red and processed meat. The Lancet Oncology http://www.thelancet.com/journals/lanonc/article/PIIS1470-2045(15)00444-1/abstract

Comment by SC-WFO: proof not provided; weak methodology

This source purports to be a widely encompassing review of all the different ways in which diet choices may impact all predominant types of cancer. The only (and weak at that) association that could be identified was for processed meat and colon cancer, but not for unprocessed meat, and not for any other type of cancer. Therefore, this source cannot support the sweeping statement that reduction of excessive livestock production would deliver health benefits, because first of all it does not define what is excessive, and secondly, at best rather modest health benefits of reduced colon cancer incidence would be associated with processed meats, but not any other livestock product, and not for any other type of cancer.

Secondly, close inspection of the documentation reveals that the authors ultimately hinged their entire conclusion on just one single scientific investigation from the year 2011, rather than the 800 which they purportedly had reviewed. This 2011 paper in turn shows severe signs of p-hacking and therefore should be discounted as scientific evidence. Details on this weak methodology are published at: https://www.wfo-oma.org/wfo_news/consumption-of-unprocessed-red-meat-is-not-a-health-risk/

FN 31: ***If not addressed, the industrial livestock sector could increasingly threaten the livelihoods of millions of small-scale farmers, a process already underway in many areas, replicating the trend seen in the Global North. [31]***

Source FN 31: Gura, S. 2008. Industrial livestock production and its impact on smallholders in developing countries. Consultancy report to the League for Pastoral Peoples and Endogenous Livestock Development, Germany.

Comment by SC-WFO: correct source

This text is correctly supported by this source. However, we would note, that even if the general trend over the past decades has been towards concentration and industrializing parts of the livestock value chain, the great majority of livestock farmers also in the Global North are still family farms, and are not corporatized industry.

FN 32,33,34: ***such farming can build soil fertility and quality, conserve water and restore biodiversity, while minimising the use of agro-chemicals [32,33,34]***

Source FN 32: EU Biodiversity Strategy

Comment by SC-WFO: no relevance/wrong source

The documentation on the EU biodiversity strategy is just that: a strategy of how the EU wants to move forward with regards to biodiversity. The document is not a scientific proof, nor does it purport to be, how various kinds of farming can build soil fertility etc. The source could prove that the EU as a case study intends to achieve such outcomes with a certain strategy – but it is not scientific proof that it can or will achieve such outcomes. It is also not proof of having achieved such outcomes in the past. This source is therefore not relevant to what the text claims.

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Source FN 33: Broom, D.M., Galindo, F.A. and Murgueitio, E., 2013. Sustainable, efficient livestock production with high biodiversity and good welfare for animals. Proc. R. Soc. B 280, 20132025.

Comment by SC-WFO: correct source
No further comment

Source FN 34: Agricology. Tim May (Farmer). https://www.agricology.co.uk/field/farmer-profiles/tim-may Accessed 18 June 2021

Comment by SC-WFO: correct source
No further comment

FN 35: ***Globally 40% of crop calories are used as animal feed [35]***

Source FN 35: Pradhan et al., 2013. Embodied crop calories in animal products. Environ. Res. Lett. 8 044044.

Comment by SC-WFO: correct source
In the meanwhile, more up-to-date and refined modelling exercises are available, so that this source is somewhat outdated. However, the main message remains broadly the same.

FN 36,37,38: ***Globally 40% of crop calories are used as animal feed, where it can undermine food security and thereby SDG 2 due to the inefficient conversion of cereals into meat and milk. [36 37 38]***

Source FN 36: Nellemann et al., 2009. The environmental food crisis – The environment's role in averting future food crises. A UNEP rapid response assessment. United Nations Environment Programme, GRID-Arendal. www.unep.org/pdf/foodcrisis_lores.pdf

Comment by SC-WFO: no relevance/wrong source
This source describes the food security crisis of 2007/8 and its origins. The source does not mention anywhere nor implies that usage of cereals for animal feed undermines food security and SDG 2. Generally, the scientific consensus is the opposite, that vibrant livestock presence in rural communities greatly improves food crisis resilience of communities. Four primary reasons are described which caused the food crisis in 2007/8: *"1) The combination of extreme weather and subsequent decline in yields and cereal stocks; 2) A rapidly increasing share of non-food crops, primarily biofuels; 3) High oil prices, affecting fertilizer use, food production, distribution and transport, and subsequently food prices (Figure 3); and 4) Speculation in the food markets."* Livestock feed is not mentioned as a driver undermining food security, also not further in the more detailed analysis. The source is therefore not relevant to the text.

Source FN 37 Lundqvist, J., de Fraiture, C. Molden, D., 2008. Saving Water: From Field to Fork – Curbing Losses and Wastage in the Food Chain. SIWI Policy Brief. SIWI.http://www.siwi.org/documents/Resources/Policy_Briefs/PB_From_Filed_to_Fork_2008.pdf

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Comment by SC-WFO: no relevance/wrong source
This source describes topics around food wastage and in particular water wastage. It does not deal with food security issues to begin with, let alone providing evidence for how feed for livestock undermines food security. The source is therefore not relevant to the text.

Source FN 38 Cassidy et al., 2013. Redefining agricultural yields: from tonnes to people nourished per hectare. University of Minnesota. Environ. Res. Lett. 8 034015.

Comment by SC-WFO: weak methodology
In contrast to the two preceding non-relevant sources, this source does make the point that livestock feed calories could be undermining food security, due to their inefficient calorie conversion. However, neither this analysis nor the text account for the fact that nutrition is not just about calories. Livestock products provide critical amounts of proteins, vitamins, minerals and trace elements, which need to be accounted for in the nutritional balance, especially when considering food security. Both this source and the text are employing extremely weak methodology by considering calorie efficiency of food provision only.

FN 39, 40: ***Intensification of crop and animal production has led to soil degradation, [39 40]***

Source FN 39 Edmondson et al, 2014. Urban cultivation in allotments maintains soil qualities adversely affected by conventional agriculture. Journal of Applied Ecology 2014, 51, 880–889.

Comment by SC-WFO: no relevance/wrong source
This source investigates the soil quality of 15 urban gardening allotment sites in the English city of Leicester. The source does not investigate whether crop intensification, let alone animal production leads to soil degradation. The source is therefore not relevant to the text.

Source FN 40 Tsiafouli et al., 2015. Intensive agriculture reduces soil biodiversity across Europe. Global Change Biology: 21, p973– 985.

Comment by SC-WFO: correct source
This source investigates relationship between agricultural intensification and soil biodiversity, not soil degradation. The source is not relevant to this particular text passage, but it would fit as a reference to the next half sentence in the text, which is why it is evaluated as correct.

FN 41, 42: ***Intensification of crop and animal production has led to… biodiversity loss, including declines in pollinator numbers, [41 42]***

Source FN 41 World Health Organization and Secretariat of the Convention on Biological Diversity, 2015. Connecting global priorities: biodiversity and human health.

Comment by SC-WFO: no relevance/wrong source
This source is a 364-page state of knowledge review on all aspects of biodiversity and human health. On two pages out of the 364, it references to other sources that suggest that intensification of agriculture has led to biodiversity loss and declines in pollinator numbers. However, this source does not account for the various ways in which intensified agriculture

can also be contributing positively to biodiversity habitats. It is also not the intention of this source to examine the impacts of intensification on biodiversity or present the primary evidence for this. The source is concerned with a very different topic.

Source FN 42 UN Convention to Combat Desertification, 2017. Global Land Outlook.

Comment by SC-WFO: proof not provided
This source is the famous Global Land Outlook 2017 which is a major scientific effort taking stock of the global conditions and drivers of change for the global land resource. The source does consider the impact of agriculture, and that agriculture can be a driver of biodiversity loss. However, the documentation correctly does not draw a simplistic connection between intensification of crop and animal production and biodiversity loss. It rather presents a differentiated picture of which kinds of agricultural practices can be damaging to the land (not just biodiversity aspects). Damaging practices are not related to the degree of intensiveness. Therefore, this source does not provide the proof for the statement made in the text.

FN 43, 44, 45: ***Intensification of crop and animal production has led to…overuse and pollution of water (43 44 45]***

Source FN 43 Mekonnen, M. and Hoekstra, A., 2012. A global assessment of the water footprint of farm animal products. Ecosystems: DOI: 10.1007/s10021-011-9517-8

Comment by SC-WFO: proof not provided
This source is a well-done and detailed analysis of the water footprint required for producing farm animal products. However, the source does not provide any analysis as to whether such water footprints represent an "*overuse*" of water resources, presumably meaning that more water is utilized than can be restored on a sustainable basis to the respective eco-systems. The source also does not provide any analysis about water pollution. Therefore, the source doe not provide proof for the statement made in the text.

Source FN 44 World economic and social survey, 2011. United Nations

Comment by SC-WFO: proof not provided
This source provides on 251 pages a comprehensive overview on the need and possibility for a green technological transformation. The source does mention numerous times the need to conserve water and groundwater resources and to prevent pollution, and why and which better technologies are required. However, throughout the report, the source does not make a connection between intensification of crop and animal production and overuse or pollution of water. Therefore, the source doe not provide proof for the statement made in the text.

Source FN 45 World Bank Group, 2019. Quality Unknown

Comment by SC-WFO: proof not provided; weak methodology
This source says in its summary that intensification of agriculture is one of the forces driving water quality challenges around the world. But throughout the text, the report fails to substantiate this claim. On the contrary, on page 70, the report says that it is usually

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extensification which creates problems. In places the report makes sweeping statements which are not substantiated with neither sources, nor analysis nor evidence, such as this one: "*there is no doubt that there are a growing number of cases in which highly intensive forms of agriculture, such as intensive animal husbandry, is vastly more damaging than the typical form of extensification captured in regressions.*" Therefore, this source provides neither proof for the statements in the text, and is moreover characterized by poor methodology itself.

FN 46, 47: ***Intensification of crop and animal production has led to …air pollution [46 47]***

Source FN 46: Lelieveld et al,, 2015. The contribution of outdoor air pollution sources to premature mortality on a global scale. Nature, Vol 525.

Comment by SC-WFO: proof not provided
This source calculates that fine particulate matter with a diameter smaller than 2.5 micrometers is responsible for 3.3 million deaths per year globally, predominantly in Asia and mostly from heating and cooking. The source also calculates that agriculture would be the largest relative source of such particles in the air in Eastern USA, Russia and Europe. However, overall, the emissions rate is so low in these countries, that for instance for the United States the total annual mortality would be in the low thousands, far below the statistical significance levels of such calculations. In other words, the emissions account for a non-measurable small number of deaths. Therefore, this source does not provide proof for the statement that agriculture, let alone in particular intensified agriculture or animal production, leads to dangerous levels of air pollution.

Source FN 47: IPBES, 2019. The Global Assessment report on biodiversity and ecosystem services.

Comment by SC-WFO: no relevance/wrong source
This source reviews on 1148 pages all the different ways in which human civilization impacts biodiversity and ecosystems. While the word agriculture is mentioned 700 times in the document, only one out of these 1148 pages discusses in vague terms directly the impact of agriculture. It is not a source that discusses specifically the impact of intensification of agriculture and animal production on air pollution, and therefore is not a suitable source for this statement in the text.

FN 48: ***Demand for soya has led to the expansion of farmland into forests, with concomitant biodiversity loss and the release of stored carbon. [48]***

Source FN 48: FAO and UNEP, 2020. The State of the World's Forests 2020. Forests, biodiversity and people. Rome. DOI: https://doi.org/10.4060/ca8642enEU Biodiversity Strategy

Comment by SC-WFO: proof not provided
This source describes that 40% of tropical deforestation is caused by large-scale commercial agriculture for primarily three products of cattle-ranching, soya beans and oil palm. The report does not split the 40% up between the three. More importantly, the report does not provide a proof that it is demand for soya, which is driving the expansion. On the contrary, it states that *"deforestation and forest degradation are really driven by many political and socio-economic forces interacting at the global to local levels*." (p 82). In other words, the source says that it is

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supply factors which drive deforestation. Therefore, this source does not provide proof for the statement that demand for soya leads to expansion of farmland into forests.

FN 49: ***The former Director-General of the FAO highlighted the danger of small-scale livestock farmers being "pushed aside by expanding large capital-intensive operations.[49]***

Source FN 49: http://www.fao.org/news/story/en/item/1098231/icode/ Accessed 15 July 2020

Comment by SC-WFO: correct source
The DG also said the following at the same occasion: *"The livestock sector is a mainstay for food security and rural livelihoods and the international community must work together to make sure it achieves its potential contribution to sustainable development."*

FN 50: ***There is scientific recognition that the best kind of animal welfare entails not only avoiding cages and crates and overcrowding but also providing opportunities for animals to have positive experiences, to experience a good quality of life and to be kept in conditions which facilitate their capacity for pleasurable feelings such as companionship.[50]***

Source FN 50: Mellor, D., 2016. Updating Animal Welfare Thinking: Moving beyond the "Five Freedoms" towards "A Life Worth Living". Animals 6, 21.

Comment by SC-WFO: correct source
Even if this is a correctly referenced source, it should be noted that "*the best kind of animal welfare*" requires a normative value judgement for *"best"*, for which it is not specified who is making this judgement. If for instance, *"best"* was defined in terms of economic outcome for the livestock keeper, then the result would likely be very different than if *"best"* is defined in terms of moral well-being of animal rights advocates. This then opens the discussion who of these two (or other) judges have the right to cast this judgement and on which legal strength? In the case of the statement above, *"best"* was defined on the basis of the latter.

Whether it is possible to define *"best"* in terms of an animal's own judgement or perspective on the matter, is a highly contested separate question concerning whether highly sentient animals are capable of such humanesque judgement. In most cases, the practical alternative available to such an animal would be not to be alive at all, because its economic productivity might not be high enough to the livestock keeper, and thus the keeper would not have let this animal be born to begin with. Here the human discussant reaches a problematic end: are animals able to contemplate such judgement? As the answer must be negative, then the animal forfeits its right to enter its own perspective into the debate, because it cannot surmise all consequences and be responsible for them.

FN 51: ***The FAO has stated: 'A paradigm shift has become urgent. Animals are to be addressed as living beings to take care of and valorize, not only as a source of commodities to exploit' [51]***

Source FN 51: FAO. Animal Welfare L Archives. Newsletter No 108, 15 January 2020 https://listserv.fao.org/scripts/wa-fao.exe?A0=FAO-ANIMALWELFARE-L&S=b Accessed 3 February 2021.

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Comment by SC-WFO: proof not provided
It is not true that the FAO made this statement. The statement was made by the Editor of a Newsletter among an FAO Sustainable Livestock Technical Network. It is not apparent who that Editor is, but it is clear that this is not an FAO official position.

FN 52, 53, 54: ***Industrial production is dependent on routine use of antimicrobials to prevent the diseases that arise when animals are kept in poor conditions. [52 53 54]***

Source FN 52: Antimicrobials in agriculture and the environment: reducing unnecessary use and waste, by Review on Antimicrobial Resistance, 2015.

Comment by SC-WFO: proof not provided
This source states the opposite of the above. On page 15 it says: *"However, there is growing evidence to suggest that antibiotics used as growth promoters do not have as much economic benefit as previously thought, particularly in countries with advanced farming techniques."* Accordingly the source does not provide proof for the statement.

Source FN 53: WHO DG opening remarks on AMR: https://www.who.int/director-general/speeches/detail/who-director-general-opening-remarks-on-antimicrobial-resistance

Comment by SC-WFO: proof not provided
This source does say that worldwide the use of antibiotics in humans, animals and agriculture is increasing. However, the source does not state that industrial production is dependent on routine use of antimicrobials. On the contrary, the DG of WHO states the opposite of the above: *"Significantly, the EU-wide ban on the use of antibiotics as growth promoters in animal feed has not weakened the region's leading position in global food production".*

Source FN 54: FAO Deputy DG opening remarks February 2016: http://www.fao.org/news/story/en/item/382636/icode

Comment by SC-WFO: proof not provided
This source does say that the global use of antibiotics in humans, animals and agriculture is problematic. However, the source does not state that industrial production is dependent on routine use of antimicrobials. On the contrary, the Deputy DG of FAO states the opposite of the above: *"the Netherlands in particular slashed the amount of drugs used in its prosperous livestock sector by almost 60 percent in recent years".*

FN 55: ***Globally, around 70% of all antibiotics are used in farm animals.[55]***

Source FN 55: Boeckel et al, 2019. Global trends in antimicrobial resistance in animals in low- and middle-income countries. Science 365, 1266 (2019)

Comment by SC-WFO: no reference/wrong source
The source is in principle correct, and the number of 70% is mentioned in this source. However, it is a very much outdated number. The EU has banned antimicrobials for growth promotion purposes already in 2006. The USA banned them in 2017, China and Brazil in 2020,

and India banned Colistin in 2019. This means that there has been a drastic reduction of antibiotics for animal feed purposes, and thus the 70% number is not current anymore.

FN 56: ***The stressful, crowded conditions of industrial agriculture contribute to the emergence, spread and amplification of pathogens. [56]***

Source FN 56: EMA (European Medicines Agency) and EFSA (European Food Safety Authority), 2017. EMA and EFSA Joint Scientific Opinion on measures to reduce the need to use antimicrobial agents in animal husbandry in the European Union, and the resulting impacts on food safety (RONAFA). [EMA/CVMP/570771/2015]. EFSA Journal 2017;15(1):4666

Comment by SC-WFO: proof not provided
This is the same source as FN 15, for which it was not a relevant source. As FN 56 it is a relevant source. However, the document does neither use the term industrial agriculture nor its implications, for describing pathogen conducive animal husbandry conditions. The source can therefore not provide proof for this statement.

FN 57: ***intensively reared animals are selectively bred to have nearly identical genomes and act as vast replication vessels for some viruses.[57]***

Source FN 57: United Nations Environment Programme. (2020). Coronaviruses: are they here to stay? United Nations Environment

Comment by SC-WFO: no reference/wrong source
The source says: "*intensive livestock rearing often produces genetic similarities within herds and flocks, making them susceptible to pathogen spillover from wild animals."* It is a similar message, but not nearly as drastic as the text above. The statement in the text is actually copy-pasted from page 23 of the "National Food Strategy, Independent Review, THE PLAN", (referenced at the end of FN 58). It is therefore a wrongly attributed source.

FN 58: ***To prevent future pandemics [58]…we need to move to 'health-oriented' systems for rearing animals in which good health is inherent in the farming system, rather than being propped up by routine use of antibiotics***

Source FN 58: This footnote is copy-pasted from footnote 24 of "National Food Strategy, Independent Review, THE PLAN"

"For a broad assessment of zoonotic disease risk, see: Jones, B. A. et al. (2013). Zoonosis emergence linked to agricultural intensification and environmental change. Proceedings of the National Academy of Sciences of the United States of America. Available at: https:// doi.org/10.1073/pnas.1208059110 For low genetic diversity enabling rapid viral spread in factory farms [the source meant to be here has been removed to become FN 57 above, however, the half sentence preceding it was not removed]. For cross-species pandemic-capable infection: A., Khatri, M. et al. (2012). Identification of swine H1N2/pandemic H1N1 reassortant influenza virus in pigs, United States. Veterinary Microbiology. Available at: https://doi.org/10.1016/j.vetmic.2012.02.014; For related poultry data: Rozins, C. and Day, T. (2016). The industrialization of farming may be driving virulence evolution. Evolutionary applications, 10(2), 189–198. Available at: https://doi.org/10.1111/eva.12442. For agricultural intensification's effect on pandemic risk: Willyard, C. (2019). Flu on the farm. Nature. Available at:

https://www.nature.com/articles/d41586-019- 02757-4. Sources all recently cited in National Food Strategy, Independent Review, July 2021 available at: https://www.nationalfoodstrategy.org/"

Comment by SC-WFO: proof not provided
First source Jones 2013: correct source. However, it is noteworthy that the conclusion of this source contradicts its own title: *"Available research inadequately addresses the complexity, context specificity, and interrelatedness of the environmental, biological, and social dimensions of zoonotic pathogen emergence and has therefore failed to generate scientific evidence to underpin effective management of zoonotic disease risk at the wildlife–livestock interface."*

Second source Khatri et al: correct source, no further comment.

Third source Rozins 2016: correct source, no further comment.

Fourth source Willyard 2019: correct source, no further comment.

Each of the four sources are correct for what they are being referred to within the footnote itself. However, none of the four sources proves the point that it is necessary *"to move to health-oriented systems for rearing animals to prevent future pandemics"* Neither of the four sources, nor collectively, therefore provide support for the statement in the text.

FN 59: ***To save our antibiotics [59]… we need to move to 'health-oriented' systems for rearing animals in which good health is inherent in the farming system, rather than being propped up by routine use of antibiotics***

Source FN 59: Review on Antimicrobial Resistance. (2016). Tackling Drug-Resistant Infections Globally Final Report and Recommendation. Review on Antimicrobial Resistance.

Comment by SC-WFO: correct source
No further comment

FN 60, 61: ***A 'one health, one welfare' approach is needed for the benefit of human wellbeing, animal welfare and sustainability. [60 61]***

Source FN 60: Pinillos. R.G., Appleby. M.C., Manteca, X., Scott-Park, F., Smith, C., Velarde, A., 2016. One Welfare - a platform for improving human and animal welfare. Vet Rec. 179(16):412-413. doi: 10.1136/vr.i5470. PMID: 27770094.

Comment by SC-WFO: correct source
No further comment

Source FN 61: WHO, 2017. One Health. https://www.who.int/news-room/q-a-detail/one-health.

Comment by SC-WFO: no reference/wrong source
This source does not mention One Welfare, nor animal welfare nor sustainability. It is not an appropriate source for the statement.

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The evaluation in detail for paper Sustainable Livestock B – Grazing for Soil, Climate and People

FN 9, 10: ***Human civilization has been built on livestock from the beginning of the bronze-age more than 5000 years ago [9] and remains the bedrock of food security for modern societies [10].***

Source FN 9: The Horse, the Wheel and Language, by David W. Anthony, Princeton University Press, 2007

Comment by SC-WFO: correct source

No further comment

Source FN 10: John Hodges FAO 1999, Animals and values in society: "Today, one has only to visit rural areas of Africa, Asia and Latin America to see the contrast with the West and the significant contribution of domestic animals"
Not valid link: http://www.fao.org/ag/aga/agap/frg/lrrd/lrrd11/3/hod113.htm
Actual reference: Hodges J 1999: Animals and values in society. Livestock Research for Rural Development. Volume 11, Article #23. http://www.lrrd.org/lrrd11/3/hod113.htm

Comment by SC-WFO: correct source

No further comment. The provided link was not valid

FN 11, 12: ***They can restore degraded ecosystems, sequester atmospheric carbon, and meet the nutritional demands of humanity. Grasslands, when properly managed, provide many social and environmental services [11] and can improve the sustainability of livestock production [12].***

Source FN 11: Horrocks, C., et al., 2019. Smart forage selection could significantly improve soil health in the tropics. Science of the Total
Environment 688: 609-621. https://doi.org/10.1016/j.scitotenv.2019.06.152

Comment by SC-WFO: proof not provided

This article only indirectly supports the statement. It analyzes different forage varieties and their respective impact on soil health parameters. It does not analyze whether grazing can restore degraded ecosystems.

Source FN 12 Elgersma, Anjo. 2015. "Grazing Increases the Unsaturated Fatty Acid Concentration of Milk from Grass-Fed Cows: A Review of the Contributing Factors, Challenges and Future Perspectives." European Journal of Lipid Science and Technology 117(9):1345–69

Comment by SC-WFO: proof not provided

This article only analyzes the increase of fatty acid concentration in milk from grazing cows, which in itself does not prove that there are social and environmental services derived from grazing, nor that livestock production becomes more sustainable that way.

FN 13, 14: ***Climate-smart options for forage-based systems (i.e., systems depending mainly on grazing) can foster soil health and soil fertility [13] restore grazing lands [14] sequester carbon, increase biodiversity, and provide extensive ecosystem services).***

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Source FN 13: Horrocks, C., et al., 2019. Smart forage selection could significantly improve soil health in the tropics. Science of the Total
Environment 688: 609-621. https://doi.org/10.1016/j.scitotenv.2019.06.152

Comment by SC-WFO: correct source
Same source as FN 11, here correctly utilized

Source FN 14: Teutscherova, N. et al., 2021. Intensive short-duration rotational grazing is associated with improved soil quality within one year after establishment in Colombia. Applied Soil Ecology. 159, 103835. https://doi.org/10.1016/j.apsoil.2020.103835

Comment by SC-WFO: correct source
No further comment

FN 15: ***The coevolution of ruminant ungulates and perennial grasses over the last 19 million years is believed to have resulted in the sequestration of 596 Pg C (petagrams / gigatons of carbon) into newly formed mollisols, leading to Cenozoic Cooling [15].***

Source FN 15: Retallack, G. (2013). Global Cooling by Grassland Soils of the Geological Past and Near Future (Vol. 41, pp. 69–86): Annual Review of Earth and Planetary Sciences.
https://doi.org/10.1146/annurev-earth-050212-124001
here is the pdf without charge:
https://www.thealliancecenter.org/wp-content/uploads/2021/10/Retallack-2013-grassland-cooling-q8ay9r.pdf

Comment by SC-WFO: correct source
No further comment

FN 16, 17, 18: ***The management of livestock for ecological as well as social and economic benefits is referred to in literature as Holistic Planned Grazing [16 17] and Adaptive Multi- Paddock (AMP) Grazing [18].***

Source FN 16: Hillenbrand, M., Thompson, R., Wang, F., Apfelbaum, S., & Teague, R. (2019). Impacts of holistic planned grazing with bison compared to continuous grazing with cattle in South Dakota shortgrass prairie. Agriculture, Ecosystems & Environment, 279, 156–168.
https://doi.org/10.1016/j.agee.2019.02.005

Comment by SC-WFO: correct source
No further comment

Source FN 17: Dowhower, S. L., Teague, W. R., Casey, K. D., & Daniel, R. (2020). Soil greenhouse gas emissions as impacted by soil moisture and temperature under continuous and holistic planned grazing in native tallgrass prairie. Agriculture, Ecosystems & Environment, 287, 106647.
https://doi.org/10.1016/j.agee.2019.106647

Comment by SC-WFO: correct source
No further comment

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Source FN 18: Teague, W. R., Apfelbaum, S., Lal, R., Kreuter, U. P., Rowntree, J., Davies, C. A., R. Conser, M. Rasmussen, J. Hatfield, T. Wang, F. Wang, Byck, P. (2016). The role of ruminants in reducing agriculture's carbon footprint in North America. Journal of Soil and Water Conservation, 71(2), 156-164. doi:10.2489/jswc.71.2.156
http://www.jswconline.org/content/71/2/156.full.pdf+html

Comment by SC-WFO: correct source
No further comment

FN 19, 20, 21: ***Grazing of this type has been found to sequester carbon in soil at the following levels:***
1.2 tons carbon per acre per year (tC/ac/yr) [19], 1.5 tC/ac/yr [20] and 0.93 tC/ac/yr [21].

Source FN 19: Teague, W. R., Apfelbaum, S., Lal, R., Kreuter, U. P., Rowntree, J., Davies, C. A., R. Conser, M. Rasmussen, J. Hatfield, T. Wang, F. Wang, Byck, P. (2016). The role of ruminants in reducing agriculture's carbon footprint in North America. Journal of Soil and Water Conservation, 71(2), 156-164. doi:10.2489/jswc.71.2.156
http://www.jswconline.org/content/71/2/156.full.pdf+html

Comment by SC-WFO: correct source
Same source as FN 18. No further comment

Source FN 20: Stanley, P. L., Rowntree, J. E., Beede, D. K., DeLonge, M. S., & Hamm, M. W. (2018). Impacts of soil carbon sequestration on life cycle greenhouse gas emissions in Midwestern USA beef finishing systems. Agricultural Systems, 162, 249-258.
https://www.sciencedirect.com/science/article/pii/S0308521X17310338?via%3Dihub

Comment by SC-WFO: correct source
Strictly speaking, the unit is ha/yr in the article. No further comment

Source FN 21: Rowntree JE, Stanley PL, Maciel ICF, Thorbecke M, Rosenzweig ST, Hancock DW, Guzman A and Raven MR (2020) Ecosystem Impacts and Productive Capacity of a Multi-Species Pastured Livestock System. Front. Sustain. Food Syst. 4:544984. doi: 10.3389/fsufs.2020.544984
https://www.frontiersin.org/articles/10.3389/fsufs.2020.544984/full

Comment by SC-WFO: correct source
Strictly speaking, the unit is ha/yr in the article. No further comment

FN 22 ***To put this into context, 0.79 GtC is 44% of yearly US greenhouse gas (GHG) emissions, which is 6.5 billion tons CO2e based on the EPA GHG inventory for 2019 [22].***

Source FN 22: EPA (2021), Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019
https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks

Comment by SC-WFO: correct source
The source is correct, however, the conversion calculation from C into CO2 eq is not provided. No further comment

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FN 23, 24, 25: ***These elevations in soil carbon concentrations are coupled with other improvements in rangeland ecology, such as increases in nitrogen stocks [23], soil moisture [24], and fine litter cover and forage biomass [25].***

Source FN 23: Mosier S, Apfelbaum S, Byck P, Calderon F, Teague R, Thompson R, Francesca Cotrufo M, Adaptive multi-paddock grazing enhances soil carbon and nitrogen stocks and stabilization through mineral association in southeastern U.S. grazing lands, Journal of Environmental Management, Volume 288, 2021, 112409, ISSN 0301-4797, https://doi.org/10.1016/j.jenvman.2021.112409

Comment by SC-WFO: correct source
No further comment

Source FN 24: Dowhower, S. L., Teague, W. R., Casey, K. D., & Daniel, R. (2020). Soil greenhouse gas emissions as impacted by soil moisture and temperature under continuous and holistic planned grazing in native tallgrass prairie. Agriculture, Ecosystems & Environment, 287, 106647. https://doi.org/10.1016/j.agee.2019.106647

Comment by SC-WFO: correct source
No further comment

Source FN 25: Hillenbrand, M., Thompson, R., Wang, F., Apfelbaum, S., & Teague, R. (2019). Impacts of holistic planned grazing with bison compared to continuous grazing with cattle in South Dakota shortgrass prairie. Agriculture, Ecosystems & Environment, 279,156–168. https://doi.org/10.1016/j.agee.2019.02.005

FN 26: ***Improved grasses and legume forages are an appropriate example of climate-smart technologies***
as can increase productivity and offset some of the yield losses linked to climate change. Tropical forages, when properly managed (e.g., planned grazing), can accumulate large amounts of carbon in soil, fix atmospheric nitrogen (legumes), inhibit soil nitrification and reduce GHG emissions [26].

Source FN 26: Rao, I. M., et al (2015). LivestockPlus: The sustainable intensification of forage-based agricultural systems to improve livelihoods and ecosystem services in the tropics. CIAT Publication.

Comment by SC-WFO: correct source
No further comment

FN 27: ***Holistic Planned Grazing: Holistic Planned Grazing allows land and livestock managers to plan for, honor, and enhance the complexity of their unique context and achieve their desired outcomes [27].***

Source FN 27: https://savory.global/wp-content/uploads/2017/02/about-holistic-planned-grazing.pdf

Comment by SC-WFO: correct source
No further comment

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FN 28: ***Key to the success of the grazing plan is the daily monitoring of plants, soil surface conditions, animal performance and overall desired outcomes. Annual monitoring of ecosystem health indicators of biological diversity is conducted to inform management using Ecological Outcome Verification methodology (EOV) [28].***

Source FN 28: https://savory.global/land-to-market/eov/

Comment by SC-WFO: correct source
No further comment

FN 29: ***The efficacy of Holistic Planned Grazing has been extensively studied and verified across a wide range of ecological factors [29].***

Source FN 29: Gosnell, Hannah & Grimm, Kerry & Goldstein, Bruce. (2020). A half century of Holistic Management: what does the evidence reveal?. Agriculture and Human Values. 10.1007/s10460-020-10016-w.

Comment by SC-WFO: correct source
No further comment

FN 30 – 44: ***Gosnell (2020) finds that peer-reviewed studies evaluating Holistic Planned Grazing (HPG) show the practice results in less use of herbicide and pesticide [30 31], increased on-farm biodiversity [32 33], improved forage and livestock production [34 35], reduced bare ground [36], improved stream and riparian health [37], improved soil respiration, topsoil depth, organic matter, and overall soil health [38 39 40], improved soil–water content, water holding capacity and hydrological function [41 42 43], and improved nutrient availability and retention [44].***

Source FN 30: Sherren, K., J. Fischer, and I. Fazey. 2012. Managing the grazing land- scape: Insights for agricultural adaptation from a middrought photo-elicitation study in the Australian sheep-wheat belt. Agricultural Systems 106 (1): 72–83.

Comment by SC-WFO: correct source

Source FN 31: Ferguson, B.G., S.A. Diemont, R. Alfaro-Arguello, J.F. Martin, J. Nahed-Toral, D. Alvarez-Solis, and R. Pinto-Ruiz. 2013. Sustainability of holistic and conventional cattle ranching in the seasonally dry tropics of Chiapas, Mexico. Agricultural Systems 120: 38–48.

Comment by SC-WFO: correct source
No further comment

Source FN 32: Yestrau, M.A. 2008. Holistic Management, BSE, and adaptation: A Canadian prairie perspective. Unpublished master's thesis, University of Manitoba, Canada.

Comment by SC-WFO: correct source
The main outcome of this study focused on the positive social and community outcomes of holistic grazing management. However, increase of biodiversity was also shown to be an outcome. Therefore, the source is correct. No further comment

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Source FN 33: McCosker, T. 2000. Cell grazing—The first ten years in Australia. Tropical Grasslands 34: 207–218.

Comment by SC-WFO: correct source
No further comment

Source FN 34: Ortega-S, J., S.D.Lukefahr Alfonso, and F.C. Bryant. 2013. Optimum stocking rate, monitoring, and flexibility: Key components of successful grazing management programs. Rangelands 35 (5): 22–27.

Comment by SC-WFO: correct source
No further comment

Source FN 35: Norton, B.E., M. Barnes, and R. Teague. 2013. Grazing management can improve livestock distribution. Rangelands 35 (5): 45–51.

Comment by SC-WFO: correct source
No further comment

Source FN 36: Earl, J., and C. Jones. 1996. The need for a new approach to grazing management—Is cell grazing the answer? Rangelands Journal 18: 327–350.

Comment by SC-WFO: correct source
No further comment

Source FN 37: Sovell, L.A., B.C. Vondracek, J.A. Frost, and K.G. Mumford. 2000. Impact of rotational grazing and riparian buffers on physiochemical and biological characteristics of Southeast Minnesota, USA streams. Environmental Management 26: 629–641.

Comment by SC-WFO: correct source
No further comment

Source FN 38: Ferguson, B.G., S.A. Diemont, R. Alfaro-Arguello, J.F. Martin, J. Nahed-Toral, D. Alvarez-Solis, and R. Pinto-Ruiz. 2013. Sustainability of holistic and conventional cattle ranching in the seasonally dry tropics of Chiapas, Mexico. Agricultural Systems 120: 38–48.

Comment by SC-WFO: correct source
Same source as FN 31. No further comment

Source FN 39: Stinner, D.H., B.R. Stinner, and E. Martsolf. 1997. Biodiversity as an organizing principle in agroecosystem management: Case studies of holistic resource management practitioners in the USA. Agriculture, Ecosystems & Environment 62: 199–213.

Comment by SC-WFO: correct source
No further comment

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Source FN 40: Xu, S., S. Jagadamma, and J. Rowntree. 2018. Response of grazing land soil health to management strategies: A summary review. Sustainability 10 (12): 4769.

Comment by SC-WFO: correct source
No further comment

Source FN 41: Weber, K.T., and B.S. Gokhale. 2011. Effect of grazing on soil-water content in semiarid rangelands of southeast Idaho. Journal of Arid Environments 75 (5): 464–470.

Comment by SC-WFO: correct source
No further comment

Source FN 42: McCosker, T. 2000. Cell grazing—The first ten years in Australia. Tropical Grasslands 34: 207–218.

Comment by SC-WFO: correct source
Same source as FN 33. No further comment

Source FN 43: Earl, J., and C. Jones. 1996. The need for a new approach to grazing management—Is cell grazing the answer? Rangelands Journal 18: 327–350.

Comment by SC-WFO: correct source
Same source as FN 36. No further comment

Source FN 44: Teague, W.R., S.L. Dowhower, S.A. Baker, N. Haile, P.B. DeLaune, and D.M. Conover. 2011. Grazing management impacts on vegetation, soil biota and soil chemical, physical and hydrological properties in tall grass prairie. Agriculture, Ecosystems & Environment 141 (3–4): 310–322.

Comment by SC-WFO: correct source
No further comment

FN 45, 46 ,47: ***By extension, increases in soil carbon inherent in improved farm and rangeland ecologies helps to mitigate climate change [45 46 47].***

Source FN 45: Neely, C., S. Bunning, and A. Wilkes. 2009. Review of evidence on drylands pastoral systems and climate change: Implication and opportunities for mitigation and adaptation. Rome: Food and Agriculture Organization of the United Nations.

Comment by SC-WFO: correct source
No further comment

Source FN 46: Teague, W.R., S. Apfelbaum, R. Lal, U.P. Kreuter, J. Rowntree, C.A. Davies, R. Conser, M. Rasmussen, J. Hatfield, T. Wang, F. Wang, and P. Byck. 2016. The role of ruminants in reducing agriculture's carbon footprint in North America. Journal of Soil and Water Conservation 71 (2): 156–164.

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Comment by SC-WFO: correct source
Same as FN 18. No further comment

Source FN 47: Rowntree, J.E., R. Ryals, M.S. DeLonge, W.R. Teague, M.B. Chiave- gato, P. Byck, T. Wang, and S. Xu. 2016. Potential mitigation of midwest grass-finished beef production emissions with soil carbon sequestration in the United States of America. Future of Food: Journal on Food, Agriculture and Society 4 (3): 31–38.

Comment by SC-WFO: correct source
No further comment

FN 48: ***The Land to Market program assists corporations with access to supply from EOV verified landbases, associated data for their own impact accounting needs, and Storytelling [48].***

Source FN 48: https://savory.global/land-to-market/

Comment by SC-WFO: correct source
No further comment

FN 49, 50: ***Rotatinuous grazing concept: Rotatinuous is an innovative grazing management concept that is environmentally sound, economically viable [49], technically and socially feasible for smallholders [50].***

Source FN 49: Savian, Jean Víctor, Radael Marinho Tres Schons, William de Souza Filho, Angel Sánchez Zubieta, Liris Kindlein, Jérôme Bindelle, Cimélio Bayer, Carolina Bremm, and Paulo César de Faccio Carvalho. 2021. "'Rotatinuous' Stocking as a Climate- Smart Grazing Management Strategy for Sheep Production." Science of the Total Environment 753.

Comment by SC-WFO: correct source
No further comment

Source FN 50: Carvalho PCDF. Harry Stobbs Memorial Lecture: can grazing behavior support innovations in grassland management? Trop Grasslands Forrajes Trop. (2013) 1:137. doi: 10.17138/TGFT(1)137-155

Comment by SC-WFO: correct source
No further comment

FN 51: ***This grazing management is a key strategy to reduce the environmental impact of grazing through lower methane (CH4) emissions systems, with 64% less CH4 production per area and 170% less CH4 emission per unit of the animal product, when compared to the traditional rotational stocking [51].***

Source FN 51: Savian JV, Schons RMT, Marchi DE, Freitas TS de, da Silva Neto GF, Mezzalira JC, et al. Rotatinuous stocking: a grazing management innovation that has high potential to mitigate methane emissions by sheep. J Clean Prod. (2018) 186:602–8. doi: 10.1016/j.jclepro.2018.03.162

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Comment by SC-WFO: correct source
No further comment

FN 52: ***Rotatinuous grazing concept also allows a greater intake of a high-quality diet of animals and herbage accumulation leading to better nutrition and immune stress response, promoting animal welfare [52].***

Source FN 52: Zubieta, A. S., Gómez, A. M., Savian, J. V., Soares Bolzan, A. M., Rossetto, J., Barreto, M. T., ... & de Faccio Carvalho, P. C. (2021). Low-intensity, high-frequency grazing positively affects defoliating behavior, nutrient intake and blood indicators of nutrition and stress of sheep. Frontiers in Veterinary Science, 8, 685.

Comment by SC-WFO: correct source
No further comment

FN 53, 54: ***Large ungulates in extensive pastoral grazing systems as a means of livelihood is one of the oldest viable and potentially sustainable grazing systems if properly managed, has considerable economic, ecological, and socio-cultural importance and provides ecosystem services (e.g., maintaining and even enhancing rangeland biodiversity), and maintains ecological integrity (e.g., act as a carbon sink) [53 54].***

Source FN 53: Uddin, M. E., & Kebreab, E. (2020). Impact of Food and Climate Change on Pastoral Industries. Frontiers in Sustainable Food Systems, 4, 200. https://doi.org/10.3389/fsufs.2020.543403

Comment by SC-WFO: correct source
No further comment

Source FN 54: Stolton, S., Dudley, N., and Zogib, L. (2019). Mobile Pastoralism and the World Heritage Convention. A DiversEarth publication (Switzerland). Available online at: https://roads-less-travelled.org/wp-content/uploads/2019/08/Mobile-Pastoralism-and-the-World-Heritage-Convention-_-For-Web.pdf

FN 55: ***Silvopastoral systems, which include trees (leguminous or not), increase forage quantity and quality, promote animal welfare, and diversify farm income. SPSs also have positive impacts for the recovery and conservation of biodiversity at farm and landscape level since the more heterogeneous structure provides habitat for fauna and flora and serves as wildlife corridors[55].***

Source FN 55: Mauricio, R.M., Ribeiro, R.S., Paciullo, D.S.C., Cangussú, M.A., Murgueitio, E., Chará, J., Estrada, M.X.F., 2019. Silvopastoral Systems in Latin America for Biodiversity, Environmental, and Socioeconomic Improvements. In: Lemaire, G., Carvalho,P .F., Kronberg, S., Recous, S. (Eds.), Agroecosystem Diversity: Reconciling Contemporary Agriculture and Environmental Quality. Elsevier, Academic Press, pp.287–297.ISBN: 9780128110508).

Comment by SC-WFO: correct source
No further comment

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FN 56, 57, 58: ***The SPS allow the intensification of cattle production based on natural processes and are recognized as an integrated approach to sustainable land use and reduce pressure on forest [56 57 58 59].***

Source FN 56: http://www.livestockdialogue.org/

> **Comment by SC-WFO: No relevance / wrong source**
> This is a reference to a generic site on many topics on livestock. There is a report referring to Silvopastoral Systems on this site, however, that is the FN 57 below.

Source FN 57: Chará J., Reyes E., Peri P., Otte J., Arce E., Schneider F. 2019. Silvopastoral Systems and their Contribution to Improved Resource Use and Sustainable Development Goals: Evidence from Latin America. FAO, CIPAV and Agri Benchmark, Cali, 60 pp.
Licence: CC BY-NC-SA 3.0 IGO. http://www.fao.org/publications/card/en/c/CA2792EN/

> **Comment by SC-WFO: correct source**
> No further comment

Source FN 58: Ruden A. et al.,. 2020. GANSO: New business model and technical assistance for the professionalization of sustainable livestock farming in the Colombian Orinoquia region. CCAFS Info Note. Cali, Colombia: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

> **Comment by SC-WFO: correct source**
> No further comment

Source FN 59: https://pastres.org/2021/06/01/camel-milk-is-going-global-how-can-it-grow-while-benefiting-pastoralists-animals-and-the-environment/

> **Comment by SC-WFO: correct source**
> No further comment

FN 60, 61: ***Some technologies, innovative methods, and knowledge that enable farmers, especially small producers, to make livestock production more competitive, profitable, sustainable, and resilient are: The Ranch Systems and Viability Planning (RSVP) [60] project provides technical assistance, training, monitoring tools and cost share for adopting new practices. It monitors baseline and post-adoption) soil carbon, water infiltration, plant diversity and abundance and biodiversity. GANSO [61]***

Source FN 60: https://www.worldwildlife.org/press-releases/world-wildlife-fund-joins-the-walmart-foundation-cargill-mcdonald-s-to-launch-million-acre-grazing-initiative-to-help-restore-grasslands-address-climate-change

> **Comment by SC-WFO: correct source**
> No further comment

Source FN 61: Ruden A. et al.,. 2020. GANSO: New business model and technical assistance for the professionalization of sustainable livestock farming in the Colombian Orinoquia region. CCAFS Info

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Note. Cali, Colombia: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

Comment by SC-WFO: correct source
Same as FN 58. No further comment

FN 62: ***Enhance Financing: Enabling innovation and novel finance mechanisms requires updating and improving accounting systems in global trade arrangements and market and consumer engagement [62].***

Source FN 62: World Bank. 2021. Opportunities for Climate Finance in the Livestock Sector: Removing Obstacles and Realizing Potential. World Bank, Washington, DC. © World Bank. https://openknowledge.worldbank.org/handle/10986/35495

Comment by SC-WFO: correct source
No further comment

FN 63: ***For these changes to lead to action on the ground, farmer-driven and regionally appropriate strategies should be enabled and developed for nature-positive production within planetary boundaries to provide healthy diets. These can be inspired by similar strategies already produced by several countries [63].***

Source FN 63: ILRI, Livestock Master Plans. https://www.ilri.org/livestock-master-plans

Comment by SC-WFO: correct source
No further comment

FN 64: ***Appropriate accounting tools, financing and governance mechanisms should be specified in the roadmaps [64].***

Source FN 64: HLPE 14: Agroecological and other innovative approaches for sustainable agriculture and food systems that enhance food security and nutrition.

Comment by SC-WFO: correct source
No further comment

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The evaluation in detail for paper Sustainable Livestock A – Scaling Best Practices and Technology

FN 8, 9: ***Ethiochicken is a privately-owned company in Ethiopia which combines a robust dual-purpose poultry breed developed by best-in-class animal genetics technologies, with advanced feed-, vaccination-, and farm management methods.[8] Within only 5 years from 2015 to 2020, the company has tripled the per person egg supply in entire Ethiopia, especially in rural communities. The company enabled the formation of 8000+ small enterprises and strengthened the socioeconomic livelihood of at least 4 million rural small-scale farmers in the country.[9]***

Source FN 8: https://www.ethiochicken.com/about/strategy

> **Comment by SC-WFO: correct source**
> No further comment

Source FN 9: https://www.finnfund.fi/en/investing/investments/ethiochicken/ (2020 number update in private communication)

> **Comment by SC-WFO: correct source**
> No further comment

FN 10: ***Sensor Technologies and Precision Livestock Farming (PLF) make it possible to monitor and condition the health situation of single animals in large scale herds such as poultry flocks, pig pens, dairy operations or cattle feedlots. Increasingly this enables individualized feeding rations and better feed conversion ratios, significant reduction of mortality, better welfare and reduction of medication.[10]***

Source FN 10: Yaneth, Stygar Anna H., Boumans Iris J. M. M., Bokkers Eddie A. M., Pedersen Lene J., Niemi Jarkko K., Pastell Matti, Manteca Xavier, A Systematic Review on Validated Precision Livestock Farming Technologies for Pig Production and Its Potential to Assess Animal Welfare, Frontiers in Veterinary Science, May 2021 https://www.frontiersin.org/article/10.3389/fvets.2021.660565, DOI 10.3389/fvets.2021.660565

> **Comment by SC-WFO: correct source**
> No further comment

FN 11, 12, 13: ***Feed Technologies to Reduce Enteric Methane are available for the ruminant livestock sector, both from natural [11] and chemical sources. [12] Some trials for such additives could almost completely eliminate enteric methane, and reductions of 50% can be routinely achieved.[13]***

Source FN 11: Ku-Vera J., Jiménez-Ocampo R., Valencia-Salazar S., Montoya-Flores D, Molina-Botero I, Arango J, Gómez-Bravo C, Aguilar-Pérez C & Solorio-Sánchez F. 2020 Role of Secondary Plant Metabolites on Enteric Methane Mitigation in Ruminants. Front. Vet. Sci. 7:584. doi:10.3389/fvets.2020.00584

> **Comment by SC-WFO: correct source**
> No further comment

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Source FN 12: Meale, S.J., Popova, M., Saro, C. et al. Early life dietary intervention in dairy calves results in a long-term reduction in methane emissions. Sci Rep 11, 3003 (2021). https://doi.org/10.1038/s41598-021-82084-9

Comment by SC-WFO: correct source
No further comment

Source FN 13: Vijn S, Compart DP, Dutta N, Foukis A, Hess M, Hristov AN, Kalscheur KF, Kebreab E, Nuzhdin SV, Price NN, Sun Y, Tricarico JM, Turzillo A, Weisbjerg MR, Yarish C and Kurt TD. 2020. Key Considerations for the Use of Seaweed to Reduce Enteric Methane Emissions From Cattle. Front. Vet. Sci. 7:597430. doi: 10.3389/fvets.2020.597430

FN 14: ***This solution can reduce up to 40% of the IPCC declared amount of GHG emissions of global agriculture.[14]***

Source FN 14: IPCC Special Report on Climate Change and Land, 2019, section 5.4; https://www.ipcc.ch/srccl/

Comment by SC-WFO: correct source
The IPCC report does not specify the number "up to 40%". It writes in section 5.5: "Options with large potential for mitigation in livestock systems include better grazing land management, with increased net primary production and soil carbon stocks, improved manure management, and higher-quality feed." In section 5.4 it details the source ranges of GHG emissions from agriculture and the food system. By implication, if the portion of cattle emitted methane in those sources can be substantially reduced or even eliminated, then up to 40% can be saved.

FN 15, 16: ***Moreover, due to geochemical properties of methane in the atmosphere, a relative reduction of methane emissions creates a large-scale direct cooling effect in the atmosphere. [15 16]***

Source FN 15: Allen, M.R., Shine, K.P., Fuglestvedt, J.S. et al. A solution to the misrepresentations of CO2-equivalent emissions of short-lived climate pollutants under ambitious mitigation. npj Clim Atmos Sci 1, 16 (2018). https://doi.org/10.1038/s41612-018-0026-8

Comment by SC-WFO: correct source
No further comment

Source FN 16: https://www.darigold.com/new-methane-math-could-take-the-heat-off-cows/

Comment by SC-WFO: correct source
No further comment

FN 17, 18: ***Dairy Development Impact on Poverty Reduction and Reducing Global Hunger, two inquiries conducted under the program of Global Agenda for Sustainable Livestock (GASL) showcase how across all household-level studies, dairy cow ownership and/or improvement of***

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dairy cow production consistently had a substantial positive and nearly always statistically significant impact on a wide range of indicators.[17 18]

Source FN 17: http://www.fao.org/3/ca0289en/ca0289en.pdf

Comment by SC-WFO: correct source
No further comment

Source FN 18: http://www.fao.org/3/ca7500en/CA7500EN.pdf

Comment by SC-WFO: correct source
No further comment

FN 19 – 30: ***Multiple Sustainability Initiatives Driven by Industry Associations, Academia and UN bodies, such as the Dairy Declaration of Rotterdam [19], the Dairy Sustainability Framework providing a holistic approach to sustainability in the dairy value chain [20], the Global Roundtable for Sustainable Beef with its review of sustainability enhancements in the value chain [21], the Responsible Meat Initiative [22] , the International Poultry Council's Declaration of Sao Paulo [23], the Global Initiative for Sustainable Eggs [24] and many more regional initiatives. Several countries and companies have also announced firm commitments to make their livestock sectors sustainable by set deadlines, for instance the Danish Agriculture and Food Council [25] to be climate neutral by 2050, the Dutch Slow Growth [26] and Better Live instituted animal welfare initiatives [27], Australian beef pledges to be carbon neutral by 2030 [28], or Brazilian beef producers guarantee deforestation free cattle in their entire supply chain within the current decade [29 30].***

Source FN 19: http://www.dairydeclaration.org/

Comment by SC-WFO: correct source
No further comment

Source FN 20: https://dairysustainabilityframework.org/

Comment by SC-WFO: correct source
No further comment

Source FN 21: https://grsbeef.org/resources/Documents/MemberResources/animals-07-00026%20(1).pdf

Comment by SC-WFO: correct source
No further comment

Source FN 22: https://www.wbcsd.org/Programs/Food-and-Nature/Food-Land-Use/FReSH

Comment by SC-WFO: correct source
The link should go to https://responsiblemeat.org/ fir direct referral to the program convened by WBCSD. No further comment

Source FN 23: https://internationalpoultrycouncil.org/wp-content/uploads/2020/10/IPC-FAO-Declaration-Poultry-Sustainable-Development.pdf

Comment by SC-WFO: correct source
No further comment

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Source FN 24: https://www.internationalegg.com/our-work/sustainability/

Comment by SC-WFO: correct source
No further comment

Source FN 25: https://csr.dk/sites/default/files/Fact%20sheet%20Danish%20Crown%20Sustainability%20Strategy.pdf

Comment by SC-WFO: correct source
The link refers to Danish Crown's company commitment to implement the Danish Agricultural and Food Council request to become climate neutral by 2050. The latter's link is: https://agricultureandfood.dk/climate-neutral-2050/climate-neutral-2050 No further comment

Source FN 26: https://www.poultryworld.net/Meat/Articles/2020/5/Study-compares-4-Dutch-broiler-production-systems-584069E/

Comment by SC-WFO: correct source
No further comment

Source FN 27: https://beterleven.dierenbescherming.nl/english/

Comment by SC-WFO: correct source
No further comment

Source FN 28: https://www.mla.com.au/research-and-development/Environment-sustainability/carbon-neutral-2030-rd/cn30/

Comment by SC-WFO: correct source
No further comment

Source FN 29: https://www.reuters.com/article/jbs-esg-idUSL2N2OC2YN

Comment by SC-WFO: correct source
No further comment

Source FN 30: https://www.marfrig.com.br/pt/sustentabilidade/plano-marfrig-verde

Comment by SC-WFO: correct source
Incomplete link: https://www.marfrig.com.br/pt/sustentabilidade/marfrig-verde-mais No further comment

FN 31 – 38: ***Real data collection, monitoring initiatives and research agendas are under way. Data about what the global livestock herd is feeding on is either sparse or non-existent, which makes decision making hazardous and projections into the future too vague. GASL has been coordinating research and policy efforts in this area since 2010. [31] Major data collection efforts are beginning to fill important gaps. For instance, LEAP, the Partnership on Livestock Environmental Assessment and Performance [32], the Global Feed Lifecycle Assessment Institute [33], the Specialty Feed Ingredients Sustainability Project [34], the Global Burden of Animal Diseases programme [35], the Livestock Antimicrobial Partnership [36] or the Global Observatory on Accurate Livestock Sciences [37] work on making data available and accessible for decision-makers. Digital data collection***

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methods allow actors to share information faster and cheaper, for better decision making, as in the case of dairy in East Africa. [38]

Source FN 31: http://www.livestockdialogue.org/en/

Comment by SC-WFO: correct source
No further comment

Source FN 32: http://www.fao.org/partnerships/leap/en/

Comment by SC-WFO: correct source
No further comment

Source FN 33: https://globalfeedlca.org/

Comment by SC-WFO: correct source
No further comment

Source FN 34: https://ifif.org/our-work/project/the-speciality-feed-ingredients-sustainability-project-sfis/

Comment by SC-WFO: correct source
No further comment

Source FN 35: https://animalhealthmetrics.org/about/

Comment by SC-WFO: correct source
No further comment

Source FN 36: https://www.slu.se/lamp

Comment by SC-WFO: correct source
No further comment

Source FN 37: https://goalsciences.org/

Comment by SC-WFO: correct source
No further comment

Source FN 38: https://www.ilri.org/research/projects/african-dairy-genetic-gains

Comment by SC-WFO: correct source
No further comment

FN 39 – 41: ***The World Farmers' Organisation (WFO) as the biggest independent voice of the global farmers, committed itself "to anchor the global food systems and to take full responsibility for the farmers' part towards sustainable food systems". [39] The WFO Scientific Council created the concept of "SAFER Foods for a Sustainable World" [40], and on this basis reviewed in a synopsis that consumption of unprocessed red meat is not a risk to health. [41]***

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Source FN 39: World Farmers' Organisation. The Farmers' Route to Sustainable Food Systems. https://www.wfo-oma.org/wfo_news/wfo-policy-paper-for-fairer-and-more-sustainable-food-systems;

Comment by SC-WFO: correct source
No further comment

Source FN 40: "SAFER" Foods for a Sustainable World. Towards Sufficient, Affordable, Farm-anchored, Ethical and Regenerative Diets and Food Production Systems. https://www.wfo-oma.org/wp-content/uploads/2021/02/WFO_SAFER-Foods-for-a-Sustainable-World.pdf

Comment by SC-WFO: correct source
No further comment

Source FN 41: Scientific Council World Farmers Organisation, July 2021: Consumption of Unprocessed Red Meat Is Not a Risk to Health; https://www.wfo-oma.org/wp-content/uploads/2021/07/SC-WFO-Synopsis-Paper-on-Unprocessed-Red-Meat-Consumption_final.pdf

FN 42: ***Livestock products and production systems differ greatly, from intensive to extensive, from arctic to tropical or from high technology to indigenous. Definitions vary, but there are at least 40 farmed animal species, with at least 7,000 breeds adapted to specific local needs and contexts [42], feeding on diverse inputs mostly inedible for humans, and producing a vast range of foods and services.***

Source FN 42: FAO, Animal Genetics. http://www.fao.org/animal-genetics/background/why-is-ag-important/en/ Accessed 21 June 2021.

Comment by SC-WFO: correct source
No further comment

FN 43, 44: ***Livestock could provide almost half of our global protein requirements while staying within key planetary boundaries [43], and more innovation will increase this share. [44]***

Source FN 43: Van Zanten, H.H.E., et. al. 2018. Defining a land boundary for sustainable livestock consumption. Global Change Biology 24: 4185– 4194. https://doi.org/10.1111/gcb.14321

Comment by SC-WFO: proof not provided
The article says: "We demonstrate that livestock raised under the circular economy concept could provide a significant, nonnegligible part (9–23 g/per capita) of our daily protein needs (~50–60 g/per capita)." It is not correct to divide the lower bound of 50 by the lower bound of 23, and then claim that this source says that almost half of the global protein requirements could be met.

Source FN 44: Mottet, A. et al 2017: Livestock: On our plates or eating at our table? A new analysis of the feed/food debate. Global Food Security 14: 1-8. https://doi.org/10.1016/j.gfs.2017.01.001

Comment by SC-WFO: proof not provided
The article does not provide a calculation that innovation will increase the share of sustainable protein within planetary boundaries.

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FN 45, 46, 47: ***Moreover, these livestock proteins are of higher quality [45 46] and 45% more affordable than plant-based proteins. [47]***

Source FN 45: Wyness L. The role of red meat in the diet: nutrition and health benefits. Proc Nutr Soc. 2016 Aug;75(3):227-32. doi: 10.1017/S0029665115004267. Epub 2015 Dec 8. PMID: 26643369.

Comment by SC-WFO: correct source
No further comment

Source FN 46: Adesogan AT, Havelaar AH, McKune SL et al. Animal source foods: Sustainability problem or malnutrition and sustainability solution? Perspective matters. Global Food Security 2020; 25: 1003252

Comment by SC-WFO: correct source
No further comment

Source FN 47: Chungchunlam, S.M.S., et al. 2020. Animal-sourced foods are required for minimum-cost nutritionally adequate food patterns for the United States. Nature Food 1, 376–381. https://doi.org/10.1038/s43016-020-0096-8

Comment by SC-WFO: proof not provided
It is true that this source calculates that a nutritionally adequate diet in the USA including animal sourced foods is 45% cheaper than a plant-based diet. However, this is not due to the cost of proteins, but due to the cost of other micronutrients that are easier to obtain via animal sourced foods.

FN 48: ***To accelerate the pace, scale and roll-out of such innovation, more and better financing facilities need to be created. A sufficient share of the value chain needs to be available to the farming community so that the required investment can pay the local cost of capital, and thus be economically viable for farmers and other investors. [48]***

Source FN 48: Burkart, S., 2020. Making money with sustainable intensification: Opportunities for the beef and dairy sector in developing countries. Poster. Cali, Colombia: Alliance of Bioversity International CIAT. https://hdl.handle.net/10568/109163

Comment by SC-WFO: correct source
No further comment

FN 49: ***Farmer- and Value Chain-Oriented, Evidence-based and Country-specific Strategy Roadmaps for Livestock and Food Systems: Strategies need to be developed in regional context leading to action on the ground, and aiming for either neutral or nature-positive production within planetary boundaries. These can be inspired by similar roadmaps already produced by several countries.[49]***

Source FN 49: ILRI, Livestock Master Plans. https://www.ilri.org/livestock-master-plans

Comment by SC-WFO: correct source
No further comment

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FN 50: ***Appropriate accounting tools, financing and governance mechanisms should be specified in the roadmaps. [50]***

Source FN 50 HLPE 14: Agroecological and other innovative approaches for sustainable agriculture and food systems that enhance food security and nutrition.

Comment by SC-WFO: correct source
No further comment

FN 51, 52: ***Human civilization has been built on livestock from initiating the bronze-age more than 5000 years ago [51] towards being the bedrock of food security for modern societies today. [52]***

Source FN 51: The Horse, the Wheel and Language, by David W. Anthony, Princeton University Press, 2007

Comment by SC-WFO: correct source
No further comment

Source FN 52: John Hodges FAO 1999, Animals and values in society: "Today, one has only to visit rural areas of Africa, Asia and Latin America to see the contrast with the West and the significant contribution of domestic animals" http://www.fao.org/ag/aga/agap/frg/lrrd/lrrd11/3/hod113.htm

Comment by SC-WFO: correct source
No further comment

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Sustainable Livestock Solution Cluster – A) Scaling Best Practices and Technology

Why is it needed? Securing a Future for Sustainable Livestock

For millennia, livestock farming[1] has provided food, clothing, power, manure and income and acted as assets, collateral and status. In 2018, there was a global stock of 38,9 billion farmed land animals.[2] This has created an unprecedented challenge: on one side, the need to increase the availability of livestock derived foods to satisfy the unmet nutritional requirements of an estimated three billion people, and contribute to reducing stunting, wasting and anaemia.[3] On the other side, many methods and scale of livestock production systems around the world present severe tests to stay within the safe operating zone of planetary boundaries.[4] This is especially with regards to biodiversity, climate change and biochemical flows[5], and ensuring healthy[6] levels of intake of meat, eggs and dairy across all populations as well as good science-based animal health and welfare within the One Health framework. A re-balancing of consumption may be beneficial in populations of high livestock product intake. With strong population growth concentrated mostly among the socioeconomically vulnerable populations in the world, the sustainability[7] challenge grows exponentially and solving it is more urgent than ever before.

Why will it work? Enable Fast Scaling of Best Practices, Technology and Management

No other human-created system is as complex, as diverse, as interdependent, as subjected to the forces of nature, and as foundational to human civilization as agriculture and the role of livestock therein. Agriculture has always thrived on innovation. Major improvements through technology, business model and organisational innovation have been shown to be achievable across every kind of livestock production system. A non-exhaustive list below showcases what is possible when best practices and innovation are applied at scale:

a) **Ethiochicken** is a privately-owned company in Ethiopia which combines a robust dual-purpose poultry breed developed by best-in-class animal genetics technologies, with advanced feed-, vaccination-, and farm management methods.[8] Within only 5 years from 2015 to 2020, the company has tripled the per person egg supply in entire Ethiopia, especially in rural communities. The company enabled the formation of 8000+ small enterprises and strengthened the socioeconomic livelihood of at least 4 million rural small-scale farmers in the country.[9] Most beneficiaries of these improvements are the livelihoods of women and children as the usual livestock keepers in these households. This case study demonstrates the power of business model innovation, high technology in intensive farming operations and public private partnership.

b) **Sensor Technologies and Precision Livestock Farming (PLF)** make it possible to monitor and condition the health situation of single animals in large scale herds such as poultry flocks, pig pens, dairy operations or cattle feedlots. Increasingly this enables individualized feeding rations and better feed conversion ratios, significant reduction of mortality, better welfare and reduction of medication.[10] PLF has the potential to be an essential instrument on the pathway to fully circular livestock production systems.

c) **Feed Technologies to Reduce Enteric Methane** are available for the ruminant livestock sector, both from natural [11] and chemical sources.[12] Some trials for such additives could almost completely eliminate enteric methane, and reductions of 50% can be routinely achieved.[13] This solution can reduce up to 40% of the IPCC declared amount of GHG emissions of global agriculture.[14] Moreover, due to geochemical properties of methane in the atmosphere, a relative reduction of methane emissions creates a large-scale direct cooling effect in the atmosphere.[15] [16] No other already proven technology solution from any sector, agriculture or other, can engineer global cooling effects at this scale.

d) **Dairy Development Impact on Poverty Reduction and Reducing Global Hunger,** two inquiries conducted under the program of Global Agenda for Sustainable Livestock (GASL) showcase how across all household-level studies, dairy cow ownership and/or improvement of dairy cow production consistently had a substantial positive and nearly always statistically significant impact on a wide range of indicators**.**[17] [18]

e) **Multiple Sustainability Initiatives Driven by Industry Associations, Academia and UN bodies,** such as the Dairy Declaration of Rotterdam[19], the Dairy Sustainability Framework providing a holistic approach to sustainability in the dairy value chain[20], the Global Roundtable for Sustainable Beef with its review of sustainability enhancements in the value chain[21], the Responsible Meat Initiative[22] , the International Poultry Council's Declaration of Sao Paulo[23], the Global Initiative for Sustainable Eggs[24] and many more regional initiatives. Several countries and companies have also announced firm commitments to make their livestock sectors sustainable by set deadlines, for instance the Danish Agriculture and Food Council[25] to be climate neutral by 2050, the Dutch Slow Growth[26] and Better Live instituted animal welfare initiatives[27], Australian beef pledges to be carbon neutral by 2030[28], or Brazilian beef producers guarantee deforestation free cattle in their entire supply chain within the current decade[29] [30]. Each initiative sets the example for others to follow.

f) **Real data collection, monitoring initiatives and research agendas are under way.** Data about what the global livestock herd is feeding on is either sparse or non-existent, which makes decision making hazardous and projections into the future too vague. GASL has been coordinating research and policy efforts in this area since 2010.[31] Major data collection efforts are beginning to fill important gaps. For instance, LEAP, the Partnership on Livestock Environmental Assessment and Performance[32], the Global Feed Lifecycle Assessment Institute[33], the Specialty Feed Ingredients Sustainability Project[34], the Global Burden of Animal Diseases programme[35], the Livestock Antimicrobial Partnership[36] or the Global Observatory on Accurate Livestock Sciences[37] work on making data available and accessible for decision-makers. Digital data collection methods allow actors to share information faster and cheaper, for better decision making, as in the case of dairy in East Africa.[38]

g) **The World Farmers' Organisation (WFO)** as the biggest independent voice of the global farmers, committed itself *"to anchor the global food systems and to take full responsibility for the farmers' part towards sustainable food systems"*.[39] The WFO Scientific Council created the concept of *"SAFER Foods for a Sustainable World"* [40], and on this basis reviewed in a synopsis that consumption of unprocessed red meat is not a risk to health.[41]

How Will It Work? Four Levers of Change to Secure the Future of Sustainable Livestock

From the examples of pioneering solutions and initiatives we can distil four levers of change that give us the tools to secure sustainable livestock systems and reach the Sustainable Development Goals. The first is to build on the rich diversity of livestock knowledge, products and production systems. Second, we accelerate inclusive technical, institutional and societal innovation and financing thereof. Third, we improve how we measure and account for socioeconomic, health, environmental and ecosystem outcomes associated with livestock farming. Fourth, we prioritize farmer- and value chain-oriented and national/bioregional-specific strategies.

1. **Utilize Full Diversity:** livestock products and production systems differ greatly, from intensive to extensive, from arctic to tropical or from high technology to indigenous. Definitions vary, but there are at least 40 farmed animal species, with at least 7,000 breeds adapted to specific local needs and contexts[42], feeding on diverse inputs mostly inedible for humans, and producing a vast range of foods and services. Only a small share of this bounty of diversity is utilized, which makes it a valuable resource pool for solutions.
2. **Accelerating Innovation:** Better technologies in livestock farming opens up new solution spaces. We can build on the enormous progress already made in areas like circularity of resources flow, biodiversity protection, production efficiency, precision livestock farming, genetics, robotics or data sciences. Livestock could provide almost half of our global protein requirements while staying within key planetary boundaries[43], and more innovation will increase this share.[44] Moreover, these livestock proteins are of higher quality[45] [46] and 45% more affordable than plant-based proteins.[47] To accelerate the pace, scale and roll-out of such innovation, more and better financing facilities need to be created. A sufficient share of the value chain needs to be available to the farming community so that the required investment can pay the local cost of capital, and thus be economically viable for farmers and other investors.[48]
3. **Improving Accounting Systems:** Enabling innovation and finance requires updating and improving the measurements that are explicit and implicit in inter- and intragovernmental laws and regulations, in global trade arrangements, and in consumer engagement. It is critical that we revise and strengthen global accounting tools (*e.g.,* monitoring, calculating, modelling, reporting and verification systems) that help us rationalize the use of planetary resources and take better account of circular material flows, biodiversity services, human nutrition efficiency and quality of livelihoods. More complete and more robust accounting will help all stakeholders, but especially consumers and investors to properly evaluate and assess the values provided by livestock and make their decisions accordingly.
4. **Farmer- and Value Chain-Oriented, Evidence-based and Country-specific Strategy Roadmaps for Livestock and Food Systems:** Strategies need to be developed in regional context leading to action on the ground, and aiming for either neutral or nature-positive production within planetary boundaries. These can be inspired by similar roadmaps already produced by several countries.[49] In such processes, key stakeholders from farming, science, government, business, civil society and consumers can outline pathways for each of their priority livestock and livestock systems, the priority goals and where and how innovation is best applied, and what to promote or reduce. The chosen pathways should respond to comparative advantages of geography, human skills topography, agribusiness structures and local demands. Appropriate accounting tools, financing and governance mechanisms should be specified in the roadmaps.[50]

Human civilization has been built on livestock from initiating the bronze-age more than 5000 years ago[51] towards being the bedrock of food security for modern societies today.[52] Livestock is the millennial-long proven method to create healthy nutrition and secure livelihoods, a wisdom deeply embedded in cultural values everywhere. Sustainable livestock will also provide solutions for the additional challenge of today, to stay within the safe operating zone of planet Earth's boundaries, the only Earth we have.

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Grazing for Soil, Climate and People

Innovative Approaches to Livestock Management that Restores Ecosystems, Mitigates Global Warming, and Enhances Food Security

The Need for Sustainable Livestock Solutions: "For millennia, livestock farming[1] has provided food, clothing, power, manure and income and acted as assets, collateral and status. In 2018, there was a global stock of 38.9 billion farmed land animals[2]. This has created a challenge: there is a need to increase the availability of livestock derived foods to satisfy the unmet nutritional requirements of an estimated 3 billion people[3], and reduce stunting, wasting and anaemia[4]. Yet some methods and scale of livestock production systems around the world pose severe tests to stay within the safe operating zone of planetary boundaries[5], especially with regards to biodiversity, climate change, biochemical flows[6]. It is important to ensure healthy levels of intake of meat[7], eggs and dairy across all populations and achieve science-based animal health and welfare within the One Health framework. A re-balancing of consumption may help populations of high livestock product intake. With strong population growth concentrated mostly among the socioeconomically vulnerable populations in the world, the sustainability[8] challenge is more urgent than ever before."

Overview: Human civilization has been built on livestock from the beginning of the bronze-age more than 5000 years ago[9] and remains the bedrock of food security for modern societies[10]. Livestock is the millennial-long proven method to create healthy nutrition and secure livelihoods, a wisdom embedded in cultural values everywhere. Innovative approaches to livestock management that work in harmony with nature provide solutions for the challenge of today. They can restore degraded ecosystems, sequester atmospheric carbon, and meet the nutritional demands of humanity. Grasslands, when properly managed, provide many social and environmental services[11] and can improve the sustainability of livestock production[12]. Climate-smart options for forage-based systems (*i.e.*, systems depending mainly on grazing) can foster soil health and soil fertility[13] restore grazing lands[14] sequester carbon, increase biodiversity, and provide extensive ecosystem services). The names and modalities vary, but they all manage livestock in concert with nature. They include Holistic Planned Grazing, *Rotatinuous* grazing concept, Pastoralism, Silvopastoral systems (SPS) and improved forages (grasses and legumes) among others.

Soil Carbon and Climate: Livestock, when managed for soil health, are vital to mitigating climate change by stimulating grassland plants to sequester carbon. The coevolution of ruminant ungulates and perennial grasses over the last 19 million years is believed to have resulted in the sequestration of 596 Pg C (petagrams / gigatons of carbon) into newly formed mollisols, leading to Cenozoic Cooling[15]. The management of livestock for ecological as well as social and economic benefits is referred to in literature as Holistic Planned Grazing[16] [17] and Adaptive Multi-Paddock (AMP) Grazing[18]. Grazing of this type has been found to sequester carbon in soil at the following levels: 1.2 tons carbon per acre per year (tC/ac/yr)[19], 1.5 tC/ac/yr[20] and 0.93 tC/ac/yr[21]. In a best-case scenario, Teague et al. (2016) calculates the drawdown potential for AMP grazing in North America is 0.79 gigatons of carbon per year (GtC/yr). To put this into context, 0.79 GtC is 44% of yearly US greenhouse gas (GHG) emissions, which is 6.5 billion tons CO2e based on the EPA GHG inventory for 2019[22]. Worded more simply, nearly half of all US GHG emissions could be offset in North American soil using regenerative grazing. These elevations in soil carbon concentrations are coupled with other improvements in rangeland ecology, such as increases in nitrogen stocks[23], soil moisture[24], and fine litter cover and forage biomass[25].

Practices/technologies:

Improved forages: Improved grasses and legume forages are an appropriate example of climate-smart technologies as can increase productivity and offset some of the yield losses linked to climate change. Tropical forages, when properly managed (*e.g.,* planned grazing), can accumulate large amounts of carbon in soil, fix atmospheric nitrogen (legumes), inhibit soil nitrification and reduce GHG emissions[26].

Holistic Planned Grazing: Holistic Planned Grazing allows land and livestock managers to plan for, honor, and enhance the complexity of their unique context and achieve their desired outcomes[27]. Considerations include the type of environment being managed (perennially humid to dry environments), typical growing seasons, the ecoregion and type of vegetation and wildlife habitats present, water availability and distribution, culture and tradition, manager's financial capabilities, etc. No plan looks the same across farms, families, communities, regions, or year to year. Holistic decision making uses best information and knowledge, empowering each land steward. Key to the success of the grazing plan is the daily monitoring of plants, soil surface conditions, animal performance and overall desired outcomes. Annual monitoring of ecosystem health indicators of biological diversity is conducted to

inform management using Ecological Outcome Verification methodology (EOV)[28]. The efficacy of Holistic Planned Grazing has been extensively studied and verified across a wide range of ecological factors[29]. Gosnell (2020) finds that peer-reviewed studies evaluating Holistic Planned Grazing (HPG) show the practice results in less use of herbicide and pesticide[30 31], increased on-farm biodiversity[32 33], improved forage and livestock production[34 35], reduced bare ground[36], improved stream and riparian health[37], improved soil respiration, topsoil depth, organic matter, and overall soil health[38 39 40], improved soil–water content, water holding capacity and hydrological function[41 42 43], and improved nutrient availability and retention[44]. By extension, increases in soil carbon inherent in improved farm and rangeland ecologies helps to mitigate climate change[45 46 47]. These metrics enable the food and fashion) industry to inform their sourcing strategies. Savory global network partners with more than 50 corporations—a number rapidly growing—who are investing in holistic planned grazing technical assistance and EOV measurement on more than 2 million hectares through Hubs. The Land to Market program assists corporations with access to supply from EOV verified landbases, associated data for their own impact accounting needs, and storytelling[48].

***Rotatinuous* grazing concept:** *Rotatinuous* is an innovative grazing management concept that is environmentally sound, economically viable[49], technically and socially feasible for smallholders[50]. This grazing management is a key strategy to reduce the environmental impact of grazing through lower methane (CH_4) emissions systems, with 64% less CH_4 production per area and 170% less CH_4 emission per unit of the animal product, when compared to the traditional rotational stocking[51]. *Rotatinuous* grazing concept also allows a greater intake of a high-quality diet of animals and herbage accumulation leading to better nutrition and immune stress response, promoting animal welfare[52].

Pastoralism: Large ungulates in extensive pastoral grazing systems as a means of livelihood is one of the oldest viable and potentially sustainable grazing systems if properly managed, has considerable economic, ecological, and socio-cultural importance and provides ecosystem services (*e.g.*, maintaining and even enhancing rangeland biodiversity), and maintains ecological integrity (*e.g.*, act as a carbon sink) [53 54].

Silvopastoral systems (SPS): Silvopastoral systems, which include trees (leguminous or not), increase forage quantity and quality, promote animal welfare, and diversify farm income. SPSs also have positive impacts for the recovery and conservation of biodiversity at farm and landscape level since the more heterogeneous structure provides habitat for fauna and flora and serves as wildlife corridors [55]. The SPS allow the intensification of cattle production based on natural processes and are recognized as an integrated approach to sustainable land use and reduce pressure on forest [56 57 58 59].

Producer Viability: some technologies, innovative methods, and knowledge that enable farmers, especially small producers, to make livestock production more competitive, profitable, sustainable, and resilient are: *The Ranch Systems and Viability Planning (RSVP)*[60] project provides technical assistance, training, monitoring tools and cost share for adopting new practices. It monitors baseline and post-adoption) soil carbon, water infiltration, plant diversity and abundance and biodiversity. *GANSO*[61] (GANaderia SOstenible = Sustainable Livestock) is an initiative in Colombia committed to the professionalization of livestock activity through technical and financial assistance (Including SPS). It combines the intensification of livestock production with forest plantations and agricultural crops and the restoration and conservation of ecosystems. In addition, GANSO facilitates market-based climate action by certifying beef farms with sustainability standards and connecting them with retailers that sell certified beef with a premium price that consumers pay to reward producer committed to sustainability.

Why it Works-Four Levers of Change: These examples of pioneering solutions rest on four levers of change delivering the tools to achieve sustainable livestock systems and reach SDGs as follows: 1) *Build on Diversity* (Foster context relevant diversity): Recognize, reclaim, adapt to and utilize the full diversity of livestock products and production systems around the world including integrated crop-livestock, silvo- and rangeland pasture, smallholder, indigenous communities and regenerative agricultural systems. 2) *Accelerate Innovation*: Innovation in livestock farming opens up new solution spaces. Enormous progress is being made in circularity of resources flow, protecting biodiversity, production efficiency, reducing GHG, restoring soil health and quality of foods and services provided. 3) *Enhance Financing*: Enabling innovation and novel finance mechanisms requires updating and improving accounting systems in global trade arrangements and market and consumer engagement[62]. 4) *Enable Producers*: For these changes to lead to action on the ground, farmer-driven and regionally appropriate strategies should be enabled and developed for nature-positive production within planetary boundaries to provide healthy diets. These can be inspired by similar strategies already produced by several countries[63]. Appropriate accounting tools, financing and governance mechanisms should be specified in the roadmaps[64].

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SUSTAINABLE LIVESTOCK SOLUTIONS CLUSTER

Stakeholder Group C: *Solutions that aim to optimize and align consumption and production so that the sector stays within all planetary boundaries and contributes to ensuring healthy diets for all.* (16/07/2021)

The agreed unifying framing for all three Sustainable Livestock Solutions papers explains the need for the Cluster: "*For millennia, livestock farming[1] has provided food, clothing, power, manure and income and acted as assets, collateral and status. In 2018, there was a global stock of 38.9 billion farmed land animals[2]. This has created an unprecedented challenge: on one side, the need to increase the availability of livestock derived foods to satisfy the unmet nutritional requirements of an estimated 3 billion people[3], and contribute to reducing stunting, wasting and anaemia[4]. On the other side, many methods and scale of livestock production systems around the world present severe tests to stay within the safe operating zone of planetary boundaries[5]. This is especially with regards to biodiversity, climate change, biochemical flows[6] and ensuring healthy levels of intake of meat[7], eggs and dairy across all populations as well as good science-based animal health and welfare within the One Health framework. A re-balancing of consumption may be beneficial in populations of high livestock product intake. With strong population growth concentrated mostly among the socioeconomically vulnerable populations in the world, the sustainability[8] challenge grows exponentially and solving it is more urgent than ever before.*"

In line with the goal of Action Track 3 to '*boost nature positive production at scale to globally meet the fundamental human right to healthy and nutritious food, while operating within planetary boundaries*', Stakeholder Group C proposes four solutions aimed at transforming the way the world, produces, consumes and thinks about animal-sourced foods.

The solutions are proposed in the context of a scientific evidence-base showing that a significant reduction in global consumption of meat and dairy is needed if we are to achieve the Sustainable Development Goals and to meet the Paris climate targets,[9] [10] [11] [12] to reduce the environmental harms and overuse of natural resources stemming from current livestock production,[13] to lower the incidence of non-communicable disease,[14] and to minimise the use of antimicrobials[15] and the risk of the emergence of zoonotic diseases.[16]

Solution 1: Resize the livestock industry

Research shows that the production of animal sourced foods needs to be reduced by at least half globally to stay within environmental limits and planetary boundaries.[17] Consumption of livestock products exceeds healthy and sustainable levels in some countries and falls short in others. The solution lies in more equitable distribution of global production and consumption levels within planetary boundaries. [18] [19]

Overall global reduction in the consumption of animal source foods should be undertaken on a contraction and convergence basis. This would enable increased consumption of animal-sourced foods in some countries and regions and substantial reductions amongst high-consuming populations. [20] [21] [22] [23] Issues of affordability[24] would need to be addressed as would the worrying disconnect between the retail price of food and the true cost of its production in terms of harms to the environment and human health amongst others. [25] [26]

Resizing of the livestock industry should be supported by policy measures that encourage both less and better production and consumption of livestock products and reflect both the negative and beneficial externalities of livestock production. For example, by reorienting agricultural subsidies to incentivise the production of more sustainable, humane and climate-friendly foods; updating national dietary guidelines; utilising public procurement to influence change and by promoting and subsidising healthy and sustainable dietary choices whilst discouraging unhealthy choices. This would not only reduce the harms to environment caused by excessive livestock production but deliver health benefits by reducing the incidence of heart disease, obesity, type 2 diabetes and certain cancers.[27, 28, 29 30]

It is also a priority to prevent further unsustainable animal agriculture intensification in the Global South. If not addressed, the industrial livestock sector could increasingly threaten the livelihoods of millions of small-scale farmers, a process already underway in many areas, replicating the trend seen in the Global North.[31]

Solution 2: Shift towards regenerative, agroecological farming systems

The livestock sector should undergo a dramatic transformation to become genuinely sustainable and nature-positive, for example, with farmed animals being reared on the land consuming foodstuffs that humans cannot eat, such as pasture and genuine byproducts in regenerative systems such as agroecology, agroforestry, organic farming, low intensive permanent grassland, and rotational integrated crop-livestock farming. Such farming can build soil fertility and quality, conserve water and restore biodiversity, while minimising the use of agro-chemicals.[32] [33] [34]

Most of the livestock sector's detrimental environmental impacts stem from land use change, including deforestation and the use of human-edible cereals and soya as feed. Globally 40% of crop calories are used as animal feed[35] where it can undermine food security and thereby SDG 2 due to the inefficient conversion of cereals into meat and milk.[36] [37] [38] Intensification of crop and animal production has led to soil degradation,[39] [40] biodiversity loss, including declines in pollinator numbers,[41] [42] overuse and pollution of water[43] [44] [45] and air pollution.[46] [47] Demand for soya has led to the expansion of farmland into forests, with concomitant biodiversity loss and the release of stored carbon.[48] This undermines SDGs 3, 6, 12, 14 & 15.

Ending agricultural expansion for industrial livestock and feed production would be hugely beneficial to farmers, herders and other practitioners of traditional animal husbandry, who have overwhelmingly maintained sustainable, agroecological practices but whose livelihoods are threatened by climate change and sectoral intensification.

Solution 3: Support a Just Transition

Despite the urgent need to transition towards nature positive farming, there are concerns about the possible negative socio-economic impacts of the transition among farmers, supply chain workers and government ministers. These concerns should be addressed by engaging in multilateral dialogues and showcasing pathways for an equitable transition for farmers, growers and processors and how this can enable positive socio-economic changes, including job creation and GDP boost.[1]

Transition support should be provided for farmers no longer wishing to engage in livestock production, or who wish to diversify to regenerative integrated crop-livestock, silvopastoral systems, horticulture or alternative protein production. The former Director-General of the FAO highlighted the danger of small-scale livestock farmers being "pushed aside by expanding large capital-intensive operations."[49] Smallholder farmers must be helped to increase their productivity through regenerative agriculture which can increase yields while reviving degraded land.

Solution 4: Adopt good standards of farm animal welfare

The introduction of good standards of animal welfare is increasingly recognised as a key element of genuine sustainability in livestock systems. Scope for high animal welfare can be found particularly in nature-positive farming. There is scientific recognition that the best kind of animal welfare entails not only avoiding cages and crates and overcrowding but also providing opportunities for animals to have positive experiences, to experience a good quality of life and to be kept in conditions which facilitate their capacity for pleasurable feelings such as companionship.[50] The FAO has stated: "A paradigm shift has become urgent. Animals are to be addressed as living beings to take care of and valorize, not only as a source of commodities to exploit".[51]

Industrial production is dependent on routine use of antimicrobials to prevent the diseases that arise when animals are kept in poor conditions.[52] [53] [54] Indeed globally, around 70% of all antibiotics are used in farm animals.[55] The stressful, crowded conditions of industrial agriculture contribute to the emergence, spread and amplification of pathogens. [56] This leads to antimicrobial resistance in animals which can then be transferred to people. Additionally, intensively reared animals are selectively bred to have nearly identical genomes and act as vast replication vessels for some viruses.[57]

To prevent future pandemics[58] and save our antibiotics[59], we need to move to 'health-oriented' systems for rearing animals in which good health is inherent in the farming system, rather than being propped up by routine use of antibiotics. Such systems would avoid overcrowding and excessive herd and flock size. They would minimise stress, ensure that animals can perform their natural behaviours and enjoy a good quality of life. Such systems would not use routine mutilations such as castration, tail docking, teeth clipping and beak trimming.

A 'one health, one welfare' approach is needed for the benefit of human wellbeing, animal welfare and sustainability.[60] [61]

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[1] For the purpose of this solution cluster we classify all domesticated mammal and poultry species as livestock

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