QUO VADIS
GLOBAL MEAT INDUSTRY
2050
Reporting from
the Frontiers of Science

# Part 4
# Animal Protein, Climate Change and Cancer

## What Science Knows and What the Narrative Says

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Discussion Paper

CEIBS

*author*
Peer Ederer, CEIBS Zurich Campus

*language advisor*
Graham Look

*layout*
Sascha Kuriyama

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# Executive Summary

Popular media reports, based on what appear to be numerous scientific investigations, tend to urge the modern consumer to much reduce their animal protein consumption. This, most reports claim, is necessary to protect the climate as agriculture represents around a quarter of the total man-made Greenhouse Gas (GHG) emissions. Of this quarter, around 60% is said to be due to animal products, with red meats and certain cattle products, taking the lion's share. Besides climate, there would also be other environmental concerns such as water and soil degradation, deforestation, and more. It would also be healthier as red meats in particular, but also animal proteins in general, are considered to cause cancer and cardiovascular disease. Furthermore, it would be morally problematic to kill sentient animals, or to keep them under industrialized conditions. The only responsible and reasonable thing to do would therefore be to adopt a vegan lifestyle, or at least flexitarian habits with reduced intakes of animal proteins.

The authors of such publications work across the entire quality spectrum of science and media, including researchers from some of the world's most renowned universities such as Harvard, Oxford and Cambridge, journalists at the New York Times and the BBC, and policy advisors at esteemed organizations such as the World Health Organization (WHO), the Food and Agriculture Organization (FAO) and the Intergovernmental Panel on Climate Change (IPCC).

This report reviews several of the most high profile and most often cited scientific investigations on which these claims of climate and health damage are made. The report finds that each of these scientific investigations suffer from crucial methodological flaws, are careless and shoddy with referencing critical data, systematically ignore findings that do not fit the 'meat is irresponsible' narrative, and are not as numerous as they are claimed to be. Each of these criticisms can be easily retraced and verified by the reader of this report, since all materials to which it refers are readily downloadable from the internet and are marked by page.

In particular this report highlights the following shortcomings:

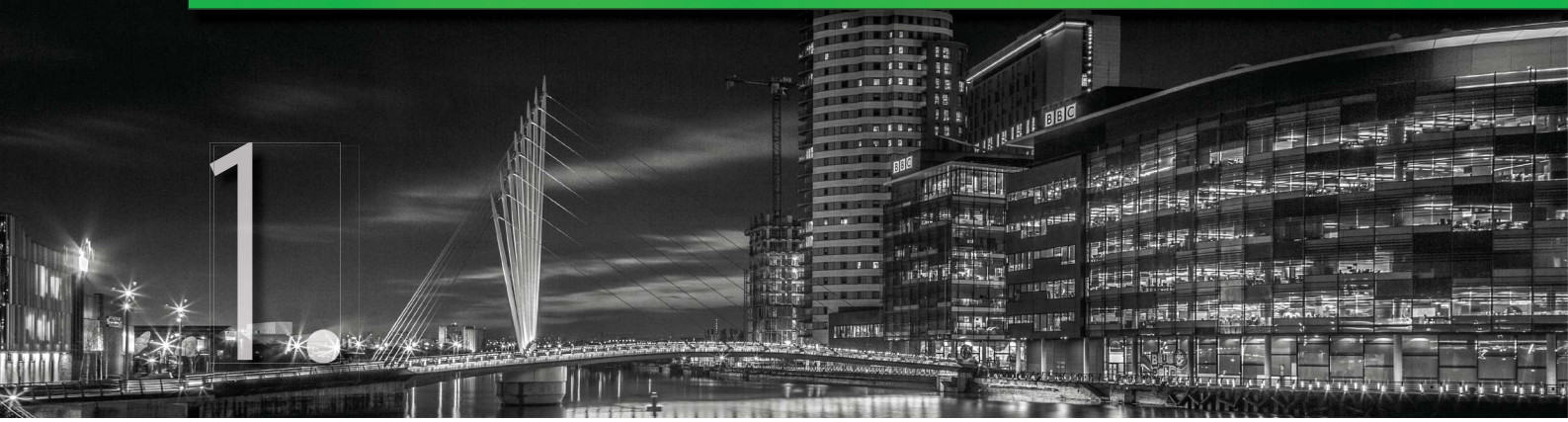
- The publications, on which much of the 'meat is irresponsible' narrative rests, use hundreds or sometimes thousands of references to other publications, for numbers, statistics and methods, which then refer yet again to hundreds of other publications. Frequently key metrics and important concepts are cited inconsistently, plainly wrong or are conjured from a convolute of references that are not relevant to the question. Many findings derive from inaccessible model simulations. True empirical investigations are rare

- Summary findings in these publications are usually expressed as established facts, when in reality they are based on estimates with broad uncertainty ranges. These uncertainty ranges can often only be found in separate methodology papers, which are harder to locate, and are shrouded in scientific and complicated jargon. In several important cases the simple arithmetic of adding up or calculating percentages cannot be replicated. Sometimes the summaries state exactly the opposite of what the evidence in the same investigation indicates
- There is a frequent bias to ignore scientific investigations that arrive at numbers that are much less alarming than the common narrative. Only studies that confirm the 'meat is irresponsible' narrative are utilized and referenced
- Deforestation of original biospheres in tropical countries is a significant problem for various reasons, not least because they cause a one-time change in the sequestered carbon stock, thus releasing GHG into the atmosphere. The typically cited reports attribute around half of the extent of deforestation to increasing demand for animal protein production. This is methodologically false. There is no causal link between regional deforestation and globally aggregated increased food demand for animal proteins. Deforestation is overwhelmingly a function of weak local sociopolitical institutions, rural poverty, crime and corruption – it is only remotely or not at all a function of food demand. Moreover, the short amortization rate for the one-time effect, which is usually applied, is methodologically equally false. Suggesting to consumers that if they reduced their animal protein consumption there would be less release of GHG emissions thanks to lower rates of deforestation is therefore wrong. The empirical evidence that does exist indicates that the one will not lead to the other. If anything, the empirical evidence shows that the regional rates of deforestation would increase if aggregate animal protein production decreases
- Enteric fermentation by ruminants (cattle, sheep, goats) releases a substantial amount of methane into the atmosphere, which can be a significant GHG contribution. However, the usual studies cited for the 'meat is irresponsible' narrative do not account for the countervailing effects of methane and carbon sequestration in soils that are being grazed by these ruminants. The topic needs more investigation to provide further evidence. The few findings that do exist point towards complete or even overcompensation of animal methane eructation by methane sequestration in the soils. This reduces the overall contribution by enteric fermentation of the global herd drastically. Furthermore, a factor not considered is what would be the natural stock of ruminants in a global eco-system undisturbed by humans. To the degree that the domesticated stock replaces the natural stock, this portion should not be considered as generating additional GHG emissions. No study which the author investigated accounts for this effect
- The 2015 WHO conclusion that red meats and processed meats are causing colorectal cancer are dubious, and potentially harmful to the global population. The studies on which WHO bases its findings openly declare that a causal link could not be identified, but that there is only, at best, a statistical association to be found. At closer inspection, the committee of scientists which provided the findings for the WHO decision repeated the same set of findings (literally) that had already been published by the same lead researcher in 2011 at Imperial College London. The research work of Imperial College seems to have been financed exclusively by a privately-run charity focused on preventing cancer

through diets. It appears that an ideological mission was the guiding impetus towards overstating a slim scientific basis towards far-reaching statements, which then found a bureaucratically procedural endorsement by the WHO

Conclusion: As at 2010 the total annual man-made GHG emissions were estimated to be 49 Gigatonnes of $CO_2$ equivalent. If a quarter of this is due to agriculture, then this would be around 12 Gt. Half of this amount is supposedly caused by land use changes, primarily deforestation, which is falsely attributed to food production. The real cause for deforestation is poverty, weak institutions, crime and corruption, and not the need to grow more food. Of the remaining 6 Gt, enteric fermentation fermentation is estimated to account for between 1.6 and 2 Gt. However, if compensating methanotrophic activity should be estimated with the currently available (meagre) knowledge, then we would need to conclude that all or almost all of this is compensated by bacteria. This compensation calculation includes also the roughly 1 Gt of manure related GHG emissions. The remaining agricultural emissions would be related to rice cultivation, organic soil cultivation and crop residue decay. In other words, while animal protein production might be largely climate-neutral, rice and organic produce cultivation are the remaining problem crops for the climate. Under these circumstances, switching to a vegetarian or vegan diet would increase the GHG emissions of agriculture, not decrease them.

The oft-repeated narrative that animal protein production is harmful to the climate and to the consumer has begun to enter received common wisdom. For instance, the singer artist Beyoncé raffles off a 30-year valid free ticket to all her concert tours to all participants promising to reduce their animal protein intake. She is clearly convinced that this is the right thing to do. This report does not speculate on who promotes this factually-wrong narrative and for what reason. Clearly there are scientists who are willing to bend, bias and selectively report the existing state of knowledge to support and confirm this narrative. The author of this report puzzles why earnest scientists are willing to do so. Science should investigate rigorously and create unbiased knowledge. It is an important debate: nothing less than the health of the global population, the environmental sustainability and survivability of our lifestyles, and the fortunes of the single largest industry of the world, the animal protein production industry, are at stake.




# Introduction

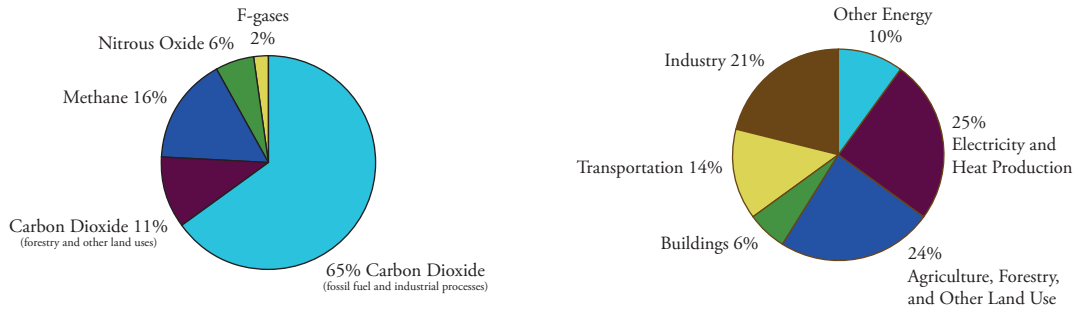
Shortly before Christmas 2018, the BBC launched a website where it is possible to evaluate the climate impact of various kinds of foods. The tool suggests, for instance, that eating a 75-gram serving of beef once or twice per week (a typical hamburger size) for an entire year produces 604 kilograms of GHG emissions, which would be equivalent to driving a car for 2482 kilometers, or heating an average home for 95 days, or taking a round trip flight between London and Malaga. The tool states that these are global averages. The tool does not state that British beef has only one third the level of GHG emissions compared with the global average – so from the outset the numbers are three times too high for a British consumer using the website.

The BBC tool offers to evaluate 35 different food options. A serving of chicken 1–2x per week for a year will produce 106 kg of GHG emissions, and a serving of peas at the same rate will produce only 1.4 kg of GHG emissions. The message: *stop eating meat, and in particular beef and dairy products, as part of your personal responsibility to protect the climate.*

What the BBC tool does not state is that the meats would provide around 25 grams of protein per serving, and the peas only 2.8 grams. USDA recommendations are 46 grams of protein per day for women and 56 grams for men. This is the equivalent of two meat servings per day, or else other products that are rich in protein, such as dairy, egg or tofu products. Meeting this daily recommendation with peas would mean eating 1.5 kilograms of peas each day. Protein-rich beans would still require between 600 and 800 grams to be eaten per day to meet the protein recommendation of the USDA.

The BBC quotes the current scientific state-of –the-art as such: 26% of all greenhouse gas emissions are caused by the production of food we eat. Out of this, 58% are due to animal products, of which 50% are due to beef and lamb products, including meat and dairy, (of which beef is responsible for more than 90%). Calculating this 26% x 58% x 50% = ~ 7.5% of all global greenhouse gas emissions are due to cattle (and a few lambs). These numbers broadly correspond to the statements of

**Exhibit 1:** Global emissions by gas and by sector




*Source: IPC, 2014*

[1] Climate Change 2014, Mitigation of Climate Change, Working Group III Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Chapter 11: Agriculture, Forestry and Other Land Use (AFOLU): downloadable here: https://www.ipcc.ch/report/ar5/wg3/

the Intergovernmental Panel on Climate Change (IPCC), of which the latest authoritative summary was published in the fifth assessment cycle, by working group III, in 2014.[1] (referred to in this report as IPCC 2014). According to the IPCC, the total annual GHG emission budget in 2000 was 40 Gt $CO_2$eq,[2] and in 2010 it was 49 Gt, of which, in each case, 24% was due to the agricultural sector.

The pedigree of the BBC tool appears impeccable. It is based on statistics that have been published by a junior researcher employed at Oxford University, Joseph Poore, and a senior researcher employed at Agroscope in Switzerland, Tomas Nemecek: Agroscope being the preeminent Swiss agricultural research institution as part of the Zurich University of Applied Sciences. The publication came out in June 2018 in the Journal *Science*, which is the most prominent global journal in the field of natural sciences.[3] It has been widely quoted throughout the world, including the highest quality newspapers. The publication references 150 endnotes and features a bibliography of more than 2000 publications listed on 125 pages. The BBC writes that:

*By analysing data from nearly 40,000 farms, 1,600 processors, packaging types and retailers, Poore and Nemecek were able to assess how different production practices and geographies have very different consequences on the planet.*

The BBC publication is also in line with numerous publications and declarations over recent years that meat and dairy consumption in general, and of cattle products in particular, is a significant contributor to climate change. The IPCC 2014 is only one of these publications. It seems to have become common knowledge that cattle emit methane gas into the atmosphere (due to enteric fermentation in their digestion system), and that methane is a greenhouse gas (GHG) which contributes to global warming. Since the global herd of cattle (and some sheep and goats) is large, and since methane ($CH_4$) is a more potent greenhouse gas than carbon dioxide ($CO_2$), the numbers add up. Therefore, the responsible thing to do, for the sake of humanity's future, is to stop eating meat, dairy and egg products, in particular those from cattle. A closer look at the evidence suggests that this common knowledge is wrong, and actions taken on this basis, may well lead to the opposite of the desired effects.

**Exhibit 2:** BBC Climate Change Food Calculator


*Source: https://www.bbc.com/news/science-environment-46459714*

[2] $CO_2$eq is the common notation for converting different impact of different gases and different industries into a common unit called $CO_2$ equivalent. Gt stands for Gigaton. A Giga stands for one billion.

[3] Reducing food's environmental impacts through producers and consumers BY J. POORE, T. NEMECEK, SCIENCE01 JUN 2018 : 987-992, DOI: 10.1126/science.aaq0216 or also downloadable for free on the author's website at: https://josephpoore.com/


# Short History of the "Meat, Dairy and Eggs Are Bad for the Climate" Narrative

Livestock emissions of GHG became a mainstream subject with the famous FAO report published in 2006, called *Livestock's long shadow: environmental issues and options*.[4] Based on a detailed Life-Cycle Analysis, the authors concluded that the global livestock industry alone was responsible for 18% of the global man-made emissions of GHG, as measured in carbon dioxide equivalents. FAO is the Food and Agriculture Organization of the United Nations, a neutral, non-partisan global organization that bases its decision-making on evidence only.

In 2009, an even more famous and widely cited report was published by the Worldwatch Institute called: *Livestock and Climate Change: What if the key actors in climate change are…cows, pigs, and chickens?*[5] This report went as far as to calculate that 51% of all annual worldwide GHG emissions arise from livestock. The report was widely received at the time, including at governments, UN institutions and climate conferences. It is still today a widely utilized and referenced piece of work.

The contents of the Worldwatch Institute report are largely fabricated. The methodology employed by their so-called scientific analysis was quickly revealed by earnest scientists to be inadmissible.[6] For instance, the authors included the respiration of $CO_2$ by livestock in their calculations. No serious scientist, including the IPCC guidelines, accepts this methodology. Every $CO_2$ molecule that is emitted by an animal was previously sequestered by a plant. It is logically impossible for these to become an additional GHG causing climate change. There were also other crucial methodological flaws.

Dr Stephen Walsh has been the Chair of the UK Vegan Society and Science Coordinator of the International Vegetarian Union. He called the Worldwatch Report *very poor science*,[7] and published a highly critical review of it. Nonetheless, despite Worldwatch's logical, procedural and mathematical flaws, the 51% number keeps floating around, and is quoted by activists.

In its 2013 update report called T*ackling Climate Change Through Livestock*,[8] the FAO authors revised down their 2006 estimation from 18% to 14.5% of global GHG emissions caused by livestock. Of these, 44% would be attributable to methane emissions and, in a different data slice, 65% would be attributable to cattle.

The IPCC consensus has settled at around that same number of 15% of global GHG being due to livestock, with estimates varying between around 50% (like Oxford's Joseph Poore used by the BBC) and 65% of these (like FAO 2013) being due to cattle for meat and dairy production.

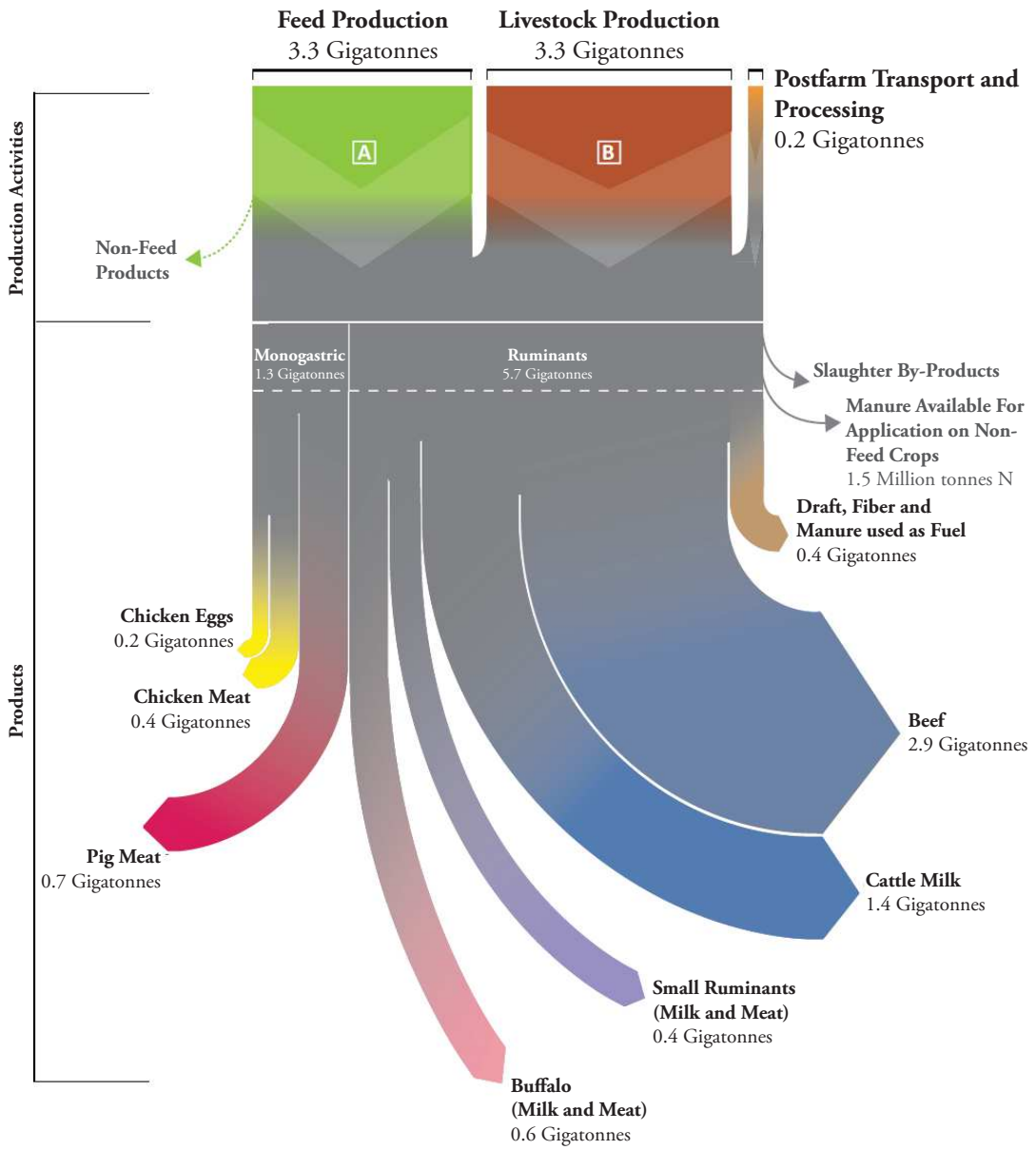
However, the IPCC consensus is not to be mistaken for broad agreement among professional

[4] Downloadable here: http://www.fao.org/3/a-a0701e.pdf
[5] Downloadable here: http://www.worldwatch.org/files/pdf/Livestock%20and%20Climate%20Change.pdf
[6] For instance: Livestock and greenhouse gas emissions: The importance of getting the numbers right, written by a group of ten prominent researchers from premier global universities and research institutions, including from FAO, EU-JRC, Wageningen University and others, in Animal Feed Science and Technology, 2011
7 https://docs.google.com/document/d/1TSuMTnsKg9dZ2gvJ-C1KVWIstvLlmbQw5UsARETSLwA/preview
[8] Downloadable here: http://www.fao.org/3/a-i3437e.pdf

researchers and experts in the livestock industry. For instance, due to strong disapproval among livestock professionals towards the FAO report, the two main authors of FAO 2013, Henning Steinfeld and Anne Mottet have since repeatedly tried to calibrate their findings, just short of fully disowning them. For instance in an article on 18 September 2018 in Thomson Reuters Foundation News, they write: *The flawed comparison and negative press about livestock may influence development plans and investments and further increase food insecurity of the 820 million people worldwide suffering from hunger.*[9]

In a detailed scientific modelling activity published in 2017, Mottet et al arrived at the significant finding that 86% of all feed given to livestock cannot be eaten by humans. She further reports that creating one kg of boneless meat in ruminant systems requires 2.8 kg of human-edible food, while monogastric systems require 3.2 kg. Thus, pork and poultry are more of a threat, if any, to human food security than cattle.[10] However, these findings do not enter the 'meat is irresponsible' narrative and receive no attention either by Beyoncé or by the BBC.

**Exhibit 3:** GHG Emissions from Global Lifestock Supply Chain




*Source: FAO, Tackling Climate Change Through Lifestock, 2013*

[9] http://news.trust.org/item/20180918083629-d2wf0

[10] Livestock: On our plates or eating at our table? A new analysis of the feed/food debate, by Anne Mottet, Cees de Haan, Alessandra Falcuccia, Giuseppe Tempio, Carolyn Opio, Pierre Gerber, Journal of Global Food Security, September 2017, https://doi.org/10.1016/j.gfs.2017.01.001

# Scientific Methodological Problems with the 'Meat, Dairy and Eggs are Bad for Health' Narrative

### 3.1 Setting the stage

The proposal that animal products are supposedly bad for human health have a long tradition, predating even the industrial revolution. Though logic, evolutionary evidence, everyday experience and modern biological insight underscores the preeminent nutritional quality of animal proteins, the myth that animal products harm human health repeatedly receives new support and new followership.

Despite this long tradition, it was surprising, that in the year 2015, the World Health Organization as the world's supposedly most neutral authority on health matters, categorized processed meat in IARC Group 1, which means there would be sufficient evidence of carcinogenicity in humans. For comparison, tobacco smoking and asbestos are listed in the same category. This merits a review of the basis on which the WHO came to this conclusion.

A closer look reveals that the WHO decision builds on many of the same studies and traditions that have already been at the center of a decades-long well-documented controversy among nutritional scientists: The relative merits of plant-based versus animal-based nutrition. The plant-based scientific group has been touting for decades that animal cholesterol fats are harmful. While the myth lingers on, scientific insight has mostly exposed this as an oversimplification. At the same time, whether intentionally or not, with the fight against the 'harmful' animal fats, the plant-based nutrition group managed to divert attention from the serious negative health effects of sugar-based products, especially carbonated soft drinks (CSD), in particular on cardiovascular systems and diabetes. Sugar has in the meanwhile received its well-deserved negative status with plenty of regulatory action and consumer behavior trying to reduce sugar consumption. Plant-based fats have also lost their shine in the course of the palm-oil problems in South East Asia. But now, the same decades-old string of biased publications and poorly conceived cohort studies resurface to turn again against animal proteins, this time on account of cancer.

A clear-minded and non-ideological appraisal of the available evidence will arrive at the same conclusion as ever: the real culprits leading to cardiovascular disease, diabetes and colorectal cancers are sugars, and to some degree salts. For these, the causal mechanisms are largely established. Animals have nothing to answer for.

### 3.2 A closer look at the WHO evidence

In October 2015 the WHO made the decision to classify red meat in the IARC Group 2A, which means that it is ***probably*** carcinogenic to humans, and processed meat was classified in Group 1, meaning that there is convincing evidence that ***it causes*** cancers in humans. (The IARC is the International Agency for Research on Cancer, an independent body within the framework of the WHO).

Between 2015 and 2018 the only publicly accessible information that provided more background on this WHO decision was a four-page Q&A that answered only the most basic questions.[11] This Q&A stated that 22 experts from 10 different countries had assessed 800 relevant studies on cancer in

[11] Downloadable here: https://www.who.int/features/qa/cancer-red-meat/en/

humans, of which 700 provided epidemiological data on red meat, and 400 provided such data on processed meat. Out of these, 10 studies would have estimated that every 50 grams of daily processed meat portion increases the risk of colorectal cancer by about 18%. As for red meat, every 100 grams of daily red meat increases the risk of colorectal cancer by about 17%. There would be 34,000 additional deaths per year from processed meats, and there might be 50,000 additional deaths from red meat, which compares with around 1 million additional deaths per year from smoking.

The American Cancer Society put these numbers into perspective: the average lifetime risk for anybody for having colorectal cancer is 5%. Every 20th person will have colon cancer for whatever reason. Eating processed meats increases that risk by 18% according to WHO, which means that among all processed meat eaters the lifetime risk of having colon cancer is now 6%.[12]

Only in 2018, the IARC working group, reporting to the WHO, released the documentation for its work, published in a 500-page tome of tightly spaced scientific language. Nonetheless, it makes for interesting reading. The report can be downloaded on the IARC website.[13] It shows that the working group investigated around 18 different kinds of cancer, but could find an association only for colorectal cancer.

For red meat, there were 15 cohort studies evaluated, whose main results are summarized here in the same sequence as in the report:

1. A New York University Women's Health Study with 100 incidental colorectal cases found **no** significant association with red meat intake
2. A Dutch study for cardiovascular disease risk factors found an association with red meat and 102 incidental colon cancer cases, but severe methodological problems were noted in the study design, which would probably negate the results
3. A Japanese cohort study with 30,221 participants did **not** find a relationship to colon cancer
4. An Adventist Health Study in California with 32,051 participants found six years later 157 colon cancer cases, of which 42 were vegetarians and 40 were only occasional meat eaters. The study established a relationship, but other confounding factors besides smoking and levels of physical activity could not be ruled out
5. A Finnish Study on the prevention of lung cancer of smokers found **no** relationship between 185 incidental colorectal cancer cases and meats, processed or not
6. In an Iowa Women's Health Study on postmenopausal women, **no** association was found for the 212 incidental colorectal cases, even including those women who had a family history with this cancer in first-degree relatives
7. A Danish Diet, Cancer and Health cohort study with 372 incidental cases reported a **null** association
8. In a Shanghai Women's Health Study with 73,224 participants and 394 incidental cases, **no** relationship was found
9. A Melbourne Collaborative Cohort Study with 451 incidental cases found a relationship
10. A Swedish Mammography Cohort with 733 incidental cases, found a relationship
11. A Singaporean Chinese Study with 941 incidental cases found **no** relationship
12. The EPIC study (European Prospective Investigation into Cancer and Nutrition) had 1329 identified colorectal cancers, and a relationship was found, and the commission found that the analysis allowed for all main potential confounding factors
13. A Nurses Health Study with 2731 colorectal cancers found **no** association
14. A multiethnic cohort study with 3404 incidental cases of colorectal cancer found **no** association
15. A UK Dietary Cohort Consortium with 579 incidental cases found **no** relationship

In summary, out of 15 cohort studies that could be identified around the world to be usefully investigated, only one study was supposedly detailed enough to prove clearly a relationship between red meat and colorectal cancer. Four other studies found a possible relationship and ten studies clearly found no association. This is all the evidence available – from around the world – on which basis the WHO says that red meat *probably* causes colorectal cancer, and no other kind of cancer. This is all the evidence available, on which basis it is claimed in big letters in media channels that red meat is dangerous to our health.

[12] https://www.cancer.org/latest-news/world-health-organization-says-processed-meat-causes-cancer.html
[13] http://publications.iarc.fr/Book-And-Report-Series/Iarc-Monographs-On-The-Identification-Of-Carcinogenic-Hazards-To-Humans/Red-Meat-And-Processed-Meat-2018

Furthermore, it has a different sound to claim that a review of 700 studies was undertaken and that from this review it was concluded that red meat was probably related to colorectal cancer, as was done in the crisp Q&A note, which was all there was for three years. The truth sounds like this: Out of the 700 studies, only 15 were relevant, and out of these 15, only one could prove a positive statistical association between red meat and colorectal cancer, and only if one eats a 100-gram serving of red meat each day, and without any evidence for what might be the causal connection.

Do we really know how this one study, the EPIC study, arrived at its supposedly strong conclusions? Is it significant that it studied mostly Europeans? Were the authors and study designers truly free of conflict of interests? On a subject on which the fate of a 10,000-billion-dollar-sales global food industry (according to the World Bank) hinges, it is justified to ask more specifically who investigated what and with what degree of confidence and independence.

### 3.3 Statistical Associations

The evidence presented by the IARC report on the associations for processed meats and colorectal cancer are somewhat stronger, but not much. Rather than repeating the same exercise as above for red meats, the following will highlight two studies which are cited frequently as justification for the claim that red meat and processed meats are dangerous for human health (for instance in the January 2019 publication by the EAT Lancet Commission).[14]

The following information is taken from an article on behalf of the Federal Commission for Nutrition, Zurich, Switzerland and published in 2015.[15] The article states:

*The reasons for the apparent adverse effects of red meat in the development or progression of atherosclerosis, diabetes and certain forms of cancer have not been clarified with certainty. It is generally assumed that there are several factors that act individually or in combination. It is also not possible to differentiate between individual sources of red meat (e. g. pork compared to beef or veal) as corresponding data is not available.*

Put briefly in non-scientific language: We have a hypothesis, which is not yet proven and we must do more work.

*Processed meat differs from non-processed in that the former often contains added ingredients such as curing salt and other salt as preservatives. Salt intake is associated with blood pressure in humans. Curing salt contains nitrite which can produce peroxynitrites in the digestive process. This may promote atherosclerosis and enhance the development of diabetes. Nitrite concentrations in the blood were correlated with endothelial dysfunction in humans and with impaired insulin sensitivity. Nitrites have also been associated with the development of gastric cancer based on case control studies, however, a more recent review of prospective cohort studies failed to confirm this relationship. The carcinogenic effect of nitrites appeared to be diminished by combined consumption with antioxidants. In addition, processed meats provide only small amounts of nitrites compared to endogenous nitrite production and to oral intake of nitrate/nitrite in vegetables.*

*Vegetarians have a lower risk of dying from cardiovascular disease or from certain types of cancer compared to meat-eating individuals. This is shown in a meta-analysis of seven studies. The relative risk of death due to coronary heart disease was 29 % lower than that of meat eaters; and for cancer the incidence risk was 18 % lower. Whether vegetarianism is responsible for the decrease in these disease risks is ultimately not clear. There is evidence that vegetarians also differ from meat eaters in other respects that lead to better health. They often have a more health-conscious lifestyle, are less likely to be overweight, smoke less and drink less alcohol.*

*In a meatless diet the sufficient supply of micronutrients such as iron, zinc and vitamin B12 may be critical. Meat provides the highest contribution to the iron supply compared with other food groups. Heme iron from meat is better absorbed than non-heme iron in plant foods such as bread. Vegans may be particularly undersupplied with nutrients (including calcium) since they do not eat any animal products; as well as meat they avoid also dairy products, fish and eggs. There are several reports of severe, irreversible neurological damage in the children of vegan mothers who did not supplement with enough vitamin B12.*

[14] https://eatforum.org/eat-lancet-commission/

[15] Health Risks Associated with Meat Consumption: A Review of Epidemiological Studies Evelyne Battaglia Richi, Beatrice Baumer, Beatrice Conrad, Roger Darioli, Alexandra Schmid, and Ulrich Keller; Int. J. Vitam. Nutr. Res., 85 (1 – 2), 2015, 70 – 78; downloadable here: https://econtent.hogrefe.com/doi/pdf/10.1024/0300-9831/a000224

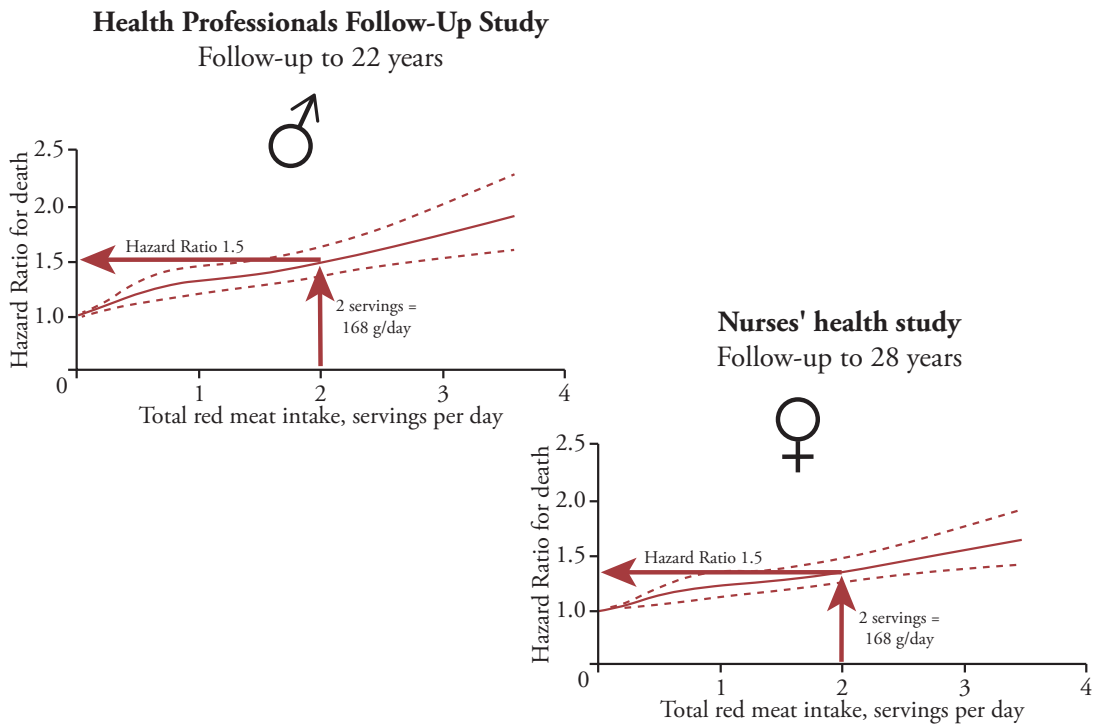
Put briefly in non-scientific language: if at all, it is the salt in processed meats that is the problem – not the meat itself. But the meat is a critical supplier of nutrition, and there is no proof that vegetarianism as such is healthier because of its dietary choices. Vegetarianism might also be a symptom of a generally healthier lifestyle, in which case the causality is the other way around.

The Swiss article quotes two famous cohort studies from the US, one is the Health Professionals Follow-up Study, the other being the Nurses Health Study. Both studies show clearly that the hazard ratio of dying within ten years is 50% higher for men who eat two servings of red meat per day (!), and 35% higher for women, compared with those who eat no red meat at all, for reasons of all possible mortality. Translated into common language: if the standard mortality for instance for an average 50 year old male is 7% within the next ten years of life, then this increases to about 10% when this male is consuming two steaks each day, see Exhibit 4. Both studies adjust for the following confounding factors: age; BMI; alcohol consumption; physical activity level; smoking status; race; menopausal status and hormone use in women; family history of diabetes mellitus, myocardial infarction or cancer; history of diabetes mellitus, hypertension, or hypercholesterolemia; and intakes of total energy, whole grains, fruits, and vegetables.

The one factor that neither study adjusts for is sugar consumption. Sugar would go a long way to explain the above results, but it is not adjusted for. For this to be true, the assumption would have to be that red meat and processed meat consumption is well correlated with sugar consumption, because other confounding factors are adjusted for. Is that true? May be. Both in the US and in Europe, the most common meal of eating meat is the burger menu: a burger, fries and a CSD, each enriched with plenty of sugar and salts.

Without adjusting for sugar and salt consumption – a known and proven risk factor for mortality – the above studies are nearly worthless with regards to evaluating the risks of meat consumption.

**Exhibit 4:** Hazard Ratio as a Consequence of Eating Red Meat




*Source: E. Battaglia Rich et al.: Health Risks associated with Meat Consumption, 2015*

### 3.4 Conflict of Interest?

One of the members of the WHO IARC Committee was Dr Teresa Norat, a Principal Research Fellow from Imperial College London, as the Subgroup Co-chair on Cancer for Humans. Dr Norat also published in the year 2011 a paper called *Red and Processed Meat and Colorectal Cancer Incidence: Meta-Analysis of Prospective Studies*. The publication can downloaded for free on the internet.[16] The conspicuous aspect about this publication is its abstract:

*The evidence that red and processed meat influences colorectal carcinogenesis was judged convincing in the 2007 World Cancer Research Fund/American Institute of Cancer Research report. Since then, ten prospective studies have published new results. Here we update the evidence from prospective studies and explore whether there is a non-linear association of red and processed meats with colorectal cancer risk.*

*When analyzed separately, colorectal cancer risk was related to intake of fresh red meat (RR for 100 g/day increase =1.17, 95% CI =1.05–1.31) and processed meat (RR for 50 g/day increase =1.18, 95% CI =1.10–1.28).*

*Conclusions: High intake of red and processed meat is associated with significant increased risk of colorectal, colon and rectal cancers. The overall evidence of prospective studies supports limiting red and processed meat consumption as one of the dietary recommendations for the prevention of colorectal cancer.*

When comparing this publication from 2011 with the wording of WHO, it becomes apparent that the IARC investigation in 2014 had arrived at exactly the same results as Dr Norat's work in 2011, even with the same wording, which then became the WHO classification. Did the WHO rubber-stamp a result that had been already agreed upon years before, under the leadership of the same researcher of Imperial College London?

The research of Dr Norat is funded by the World Cancer Research Fund International, which according to its own website:

*We champion the latest and most authoritative scientific research from around the world on cancer prevention and survival through diet, weight and physical activity so that we can help people make informed lifestyle choices to reduce their cancer risk.*

*World Cancer Research Fund International is a not-for-profit organisation that leads and unifies a network of cancer prevention charities. These charities are based in Europe, the Americas and Asia, giving us a global voice to inform people about cancer prevention.*[17]

In its annual report 2016/17, the WCRF discloses that it has received GBP 8.2 million of donations, of which it spent GBP 5.8 million on education and research. It also discloses both its mission and unique positioning in no unclear words:

*Other cancer charities focus on treatment. We're different. We focus on prevention*

Ms Marilyn Gentry, who founded this charity more than 30 years ago and is still its CEO, may well have a most noble mission in mind. No dark conspiracy needs to be assumed. Nonetheless, that should not be a sufficient basis for the WHO to state that red meat is dangerous. If there is a link, it requires more, and more truly independent research, to substantiate not only vague statistical associations but also true causal biological understanding.

None of the above-mentioned studies investigated what will happen to the health of the global population if people stopped eating meat. In order to perhaps – perhaps according to the WHO – prevent no more than 100,000 additional colorectal cancer cases (based on an assumption for which there is no causal relationship proven), a universal vegan diet might be incurring tens of millions of stunted lives and premature deaths. That is because the majority of the global population most probably does not have either the financial capacity, or the knowledge, to arrange a vegan lifestyle that is sufficient in essential nutrients and proteins.

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[16] Chan, D. S., Lau, R., Aune, D., Vieira, R., Greenwood, D. C., Kampman, E., & Norat, T. (2011). Red and processed meat and colorectal cancer incidence: meta-analysis of prospective studies. PloS one, 6(6), e20456; doi: 10.1371/journal.pone.0020456 Downloadable here: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3108955/

[17] https://www.wcrf.org/int/about-us/our-network

# 4.

# Scientific Methodological Problems with the 'Meat, Dairy and Eggs are Bad for the Climate' Narrative

### 4.1 Misleading and imprecise language and inconsistent statistics

The FAO 2013 report from above has a better scientific provenance and a wider catch of sources and modelling compared with FAO 2006. However, it still suffers from a variety of methodological shortcomings. One of these is the gap between what is reported as apparent facts and the real level of confidence that the numbers and models generate. This will be illustrated with a few examples:

The FAO 2013 report states on page 23:

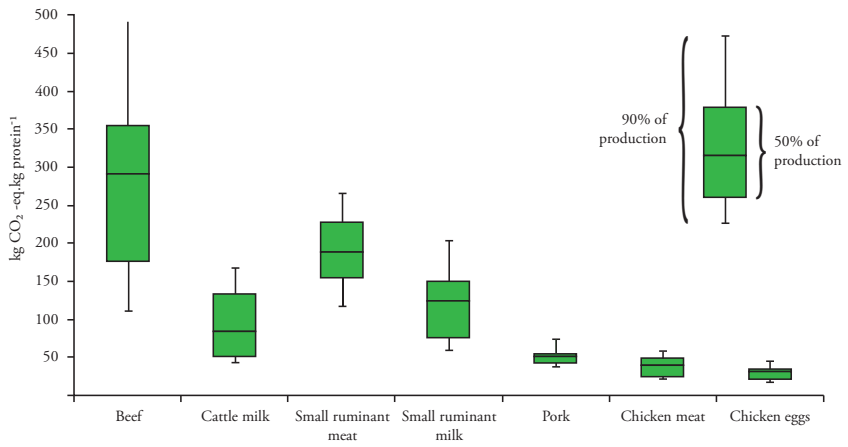
*Beef production contributes 2.9 gigatonnes CO2eq or 41 percent of total sector emissions while emissions from milk production amount to 1.4 gigatonnes or 20 percent of total sector emissions.*

In some other places, the report says that these are estimates. In general, the language of the report treats these numbers as facts, not as estimates. According to scientific practice, such numbers could only be considered scientifically validated facts if they were directly measured by at least two independent measurement devices and methodologies and would be fully replicable under all circumstances. The reality behind the generation of these numbers is far away from this scientific standard.

For instance, in the same FAO 2013 report, on page 17 and exhibit on page 16:

*For ruminant products especially, but also for pork and chicken meat and eggs, emission intensities vary greatly among producers. Different agro-ecological conditions, farming practices and supply chain management explain this heterogeneity, observed both within and across production systems.*

**Exhibit 5:** Global emission intensities by commodity




*Source: FAO, Tackling Climate Change Through Lifestock, 2013*

But even this chart and statement do not reveal the real extent of variation and uncertainty in the numbers. The methodology report for FAO 2013 does (the methodology report can be retrieved at the below footnote).[18] For instance on page xvii, the methodology report reveals that:

*Emission intensity of beef at regional level shows a great deal of diversity; ranging from 14 kg $CO_2$-eq/kg CW in Eastern Europe and the Russian Federation to 76 kg $CO_2$-eq/kg CW in South Asia…. Regional emission intensity of milk ranges from 1.6 kg $CO^2$-eq/kg FPCM to 9.0 kg $CO^2$-eq/kg FPCM.*

These are factors of 5 in variation. Variations in data are not a reason not to model and work with them. If the variations cannot be explicitly modelled, but averages need to be taken as proxies, then the resultant values should be expressed in terms of ranges of estimates, the ranges should be assigned a confidence value, and ideally the ranges should be given a t-value of measurement of reliability and validity. None of this is provided, even in the methodology section, let alone in the final report for public consumption or in the summary for policy makers.

The above mentioned IPCC 2014 report suffers from the same shortcomings. For instance, on page 822 it reports that FAOSTAT 2013 and Tubiello *et al* 2013 based on FAOSTAT numbers[19] would estimate the total GHG emissions contribution from agriculture to be between 5.2 and 5.8 Gt $CO_2$eq. But the chart, on page 822 immediately below, only shows a number of 4.3 Gt. Three other estimates from EPA and EDGAR are shown with 4.8, 5.0 and 5.3 Gt. On page 820, a summary chart shows 4.9 Gt, again sourced to FAOSTAT 2013. The original report of Tubiello 2013 states 4.6 Gt for agriculture, and between 5.4 (not 5.2!) to 5.8 Gt if biomass burning and organic soils are included. None of the numbers are consistent with one another, and only rarely are shown with confidence intervals and reliability estimates.

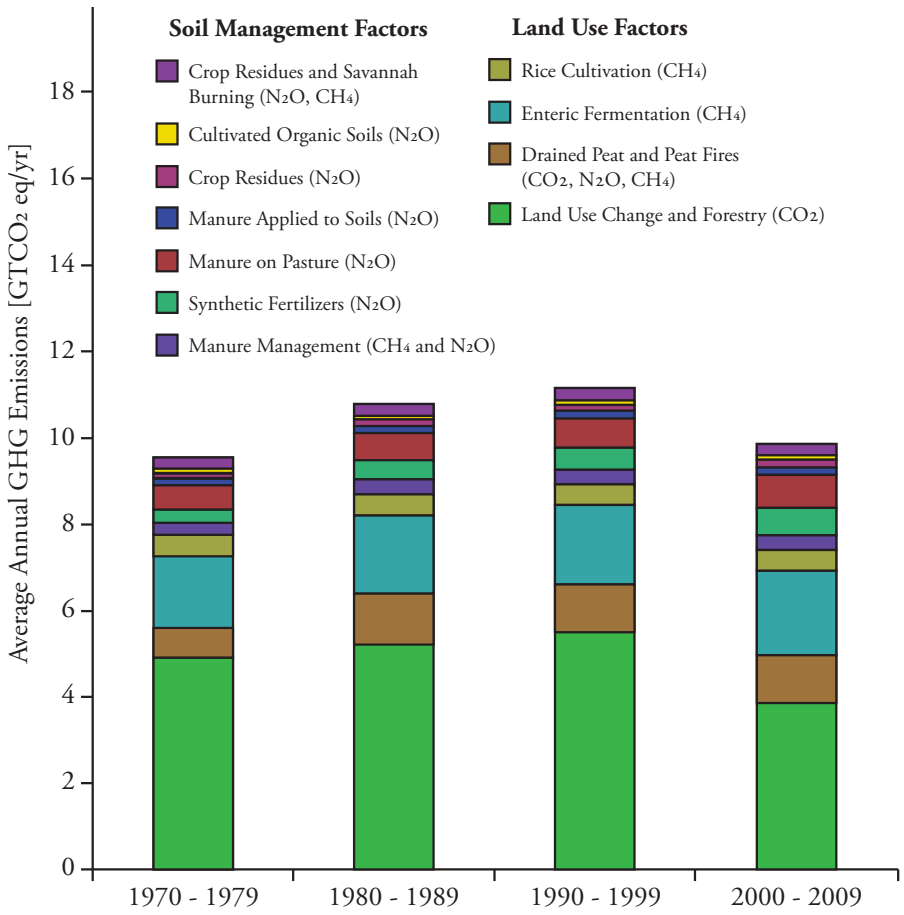
The same confusion continues with the GHG contributions from forestry and land use change (FOLU). A chart on page 827 of IPCC 2014 shows an estimate of 4.1 Gt for FOLU for the period between 2000–2007, from Baccini *et al*, but the summary chart on page 820 has a value of 3.8 for FOLU, which is from Houghton 2012, plus another 1.2 Gt for peat drainage and peat fires from yet another source, JRC 2013, for a total FOLU of 5 Gt. The FAOSTAT 2013 source has a total value of only 3.2 Gt according to page 829, including peat drainage and fire. In Tubiello 2013, peat is not even mentioned, and the net effect of deforestation is 3.4 Gt. On page 825 there is a value for the total $CO^2$ flux (which is almost only constituted by FOLU) of 4 Gt with an error margin of +/- 2.9 Gt (!) in the 95% confidence uncertainty interval. Again, none of the numbers consistent with one another. It is also unclear why the lower estimates of FAOSTAT 2013 or Tubiello 2013, based on FAOSTAT, which one would expect to be the most neutral account, are not considered in the final tally.

After all this confusion, the Tubiello 2013 adds up the agricultural sector including FOLU to a total of 8 Gt for 2010, while the IPCC 2014 adds up to 9.9 Gt for the period 2000–2009. Given that the total GHG budget was 40 Gt in 2000 and 49 Gt in 2010, this 9.9 Gt somehow equates to 24% agricultural contribution mentioned above in the introduction. How these numbers arithmetically create 24% cannot be understood. Moreover, if we used the Tubiello 2013 statistics, then it would be only 16% for the entire agricultural sector including FOLU. This is a big difference, but Tubiello based on FAOSTAT 2013 is not used in the public discourse, only the IPCC number whose derivation is unclear.

Conclusion: While the IPCC consensus is that agriculture should answer for around a quarter of the total man-made GHG emissions based on numbers that cannot be verified, other studies by reputable scientists and independent research institutions arrive at numbers that are substantially below this number. On their reckoning, it could be that aggregate agriculture is only responsible for 16% of the GHG budget.

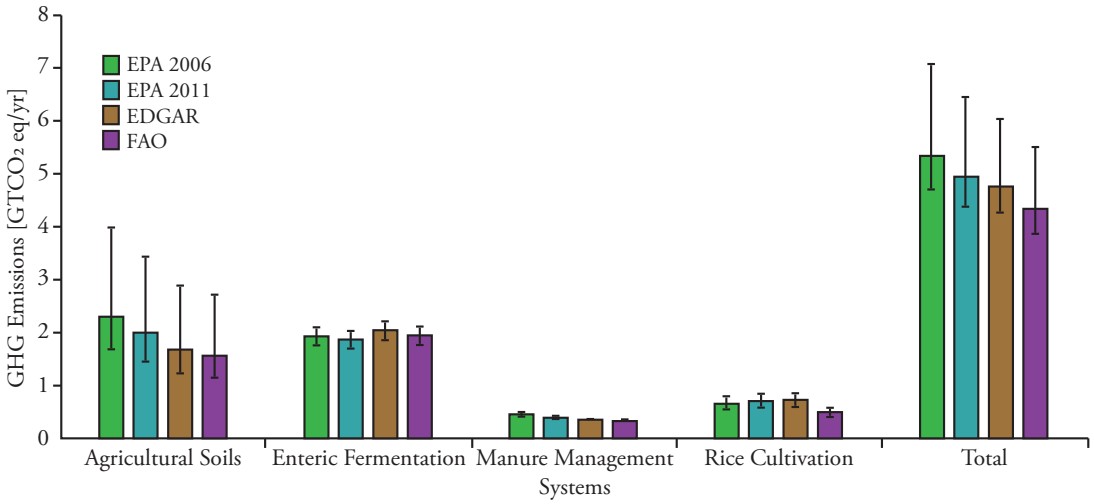
[18] Downloadable at: http://www.fao.org/docrep/018/i3461e/i3461e.pdf
[19] Downloadable at: http://www.fao.org/climatechange/36143-0fa4483057747f41c08183b702ec5954e.pdf

**Exhibit 6:** IPCC Report Page 820




*Source: Climate Change 2014, Working Group Contribution to the Fifth AR of the IPCC*

**Exhibit 7:** IPCC Report Page 822




*Source: Climate Change 2014, Working Group Contribution to the Fifth AR of the IPCC*

### 4.2 How much does enteric fermentation contribute?

Enteric fermentation by ruminants (primarily cattle, sheep and goats) is only the third largest single contribution in the agricultural sector. Around 85% of that is due to cattle. However, in most discussions, the contribution from enteric fermentation is always mentioned first, and often in a misleading way. For instance, the wording in IPCC 2014 on page 823 reveals this bias:

*All three databases agree that enteric fermentation and agricultural soils represent together about 70% of total emissions, followed by rice cultivation (9–11%)….*

This wording makes it sound as though enteric fermentation is the largest and most significant contributor. This is not true, even according to the IPCC numbers. The largest is FOLU (whatever the final number is between 3.4 and 5 Gt, see above), the second largest is management of agricultural soils, including manure and crop residues, with 2.5 Gt according to the summary chart on IPCC 2014 chart page 820, and the third largest contributor is enteric fermentation, with supposedly 2 Gt. Rice cultivation follows with 0.4 Gt. However, this 2 Gt for enteric fermentation also needs to be looked at more closely.

Where the FAO 2013 report failed to account sufficiently for regional variation, another well accepted study had been undertaken and this took into account the large spread of different productivities among livestock management. The study was also published in 2013, but only in scientific circles and has not found much public attention. It was published by Michael Herrero and nine other researchers, who are employed at the renowned Australian research organisation CSIRO, Nairobi-based ILRI and CGIAR, and Austrian IIASA.[20] Herrero *et al* modelled four animal species (cattle, small ruminants, pigs, poultry) for three products (milk, meat, eggs) under eight livestock production systems (grazing, barn, urban and combinations of them) in 28 different global regions, to study production, feed efficiency, excretion and GHG emissions. Among other findings, the report concluded that for the year 2000:

*Total non-$CO_2$ GHG emissions from the livestock sector were 2.45 Gt $CO_2$ eq. Methane from enteric fermentation from ruminants was by far the largest source with 1.6 Gt $CO_2$ eq"*…(the remainder of 0.95 arising from manure management on soils).

These numbers cannot be directly compared to the statement of FAO 2013, because FAO 2013 also includes land use changes, which will be considered in the next section. However, they can be compared to the IPCC 2014 numbers, which state that enteric fermentation accounts for 2.0 Gt $CO^2$eq, based on four investigations provided by EPA, FAO and EDGAR, finding values between 1.9 and 2.1 Gt $CO^2$eq. The more precise Herrero investigation, with 20% lower emissions for enteric fermentation, is ignored in the IPCC report. This is not a problem of the Herrero report being unknown to the IPCC 2014 authors, since the Herrero article is cited in other places in IPCC 2014.

It is to the credit of Poore/Nemecek 2018, that they used the Herrero 2013 numbers for calculating the impact of different foods on GHG emissions, which then found their way into the BBC website. As for the IPCC consensus, it can be concluded that the methodologically most sound study of assessing the production of methane by ruminants has not been incorporated. This would result in a total output of 1.6 Gt $CO^2$eq instead of 2.0 Gt for around the year 2000. To put this into perspective: the contribution of all agriculture, without FOLU, to the global GHG budget is assumed to be 4.9 Gt (IPCC 2014, p 822, see above) in 2010, so the difference of 0.4 Gt is 8%. The total output of global GHG emissions for all humanity is 40 Gt in 2010 and 49 Gt in 2010, so the difference is around 1% of the total GHG budget. This much difference is a significant number, it is as large as one third of the entire global aviation industry, which is estimated at 3.5% of the global GHG budget.

Conclusion: While the IPCC consensus is that enteric fermentation by ruminants is responsible for around 4% of the total man-made GHG emissions budget, other studies by reputable scientists from independent research institutions and employing a solid methodology arrive at numbers that are substantially below this number. It could also be that enteric fermentation is only responsible for 3% of the GHG budget.

[20] Global livestock: Biomass use, production, & GHG: Mario Herrero, Petr Havlík, Hugo Valin, An Notenbaert, Mariana C. Rufino, Philip K. Thornton, Michael Blümmel, Franz Weiss, Delia Grace, Michael Obersteiner
Proceedings of the National Academy of Sciences Dec 2013, 110 (52) 20888-20893; DOI:10.1073/pnas.1308149110 (PDF is downloadable for free at this DOI address).

### 4.3 The land-use controversy

Roughly half of what is considered to be GHG emissions for food production arises from the budget item Forest and Land Use changes (FOLU), which has a broad range of estimates. The largest portion of FOLU is deforestation. Estimates of the contribution of deforestation range from 4.11 Gt $CO^2$eq (Pan *et al* as cited in IPCC 2014 p 827) to 2 Gt by FAOSTAT 2013, as cited in IPCC p 829. The second component is peat draining and burning, which is relatively consistently estimated at 1.2 Gt.

Most of the deforestation happens in tropical regions of South America, Africa and Southeast Asia. The biosphere of a forest stores much carbon, both in its flora and in the soils. When such a forest is cleared and replaced with other uses, this represents a one-time reduction in the overall carbon stock captured in the forest. Through multiple ways, this carbon will end up in the atmosphere, either by direct burning or by gradual decomposition of the resulting wood and biomass products. In this way, deforestation contributes to a one-time effect of man-made release of additional GHG emissions to the atmosphere.

The Poore/Nemecek 2018 paper utilized a land use model with common assumptions to estimate $CO^2$ emissions and sequestration from this carbon stock change. Its calculations arrive at 61% of all 1990–2010 forest loss being attributable to agriculture. Out of this, 67% would be used for feed and pasture for animals, with cattle being dominant. The one-time carbon stock change is amortized over 20 years, and the resultant values are attributed to the various food product groups relative to their land consumption. In the example of beef meat production, this land use factor accounts for about 30% of all GHG emissions, which total 41 kg of $CO^2$eq per 100 gram of protein. For poultry meat, it accounts for 53% of a total of 4 kg of $CO^2$eq per 100 gram of protein. Further detailed results for 10 product groups plus vegetable proteins are shown in Figure 3 of the Poore/Nemecek 2018 paper.

There are two methodological problems with this approach. The first is the amortization period. Deforestation leads to a one-time release of carbon to the atmosphere, which is then amortized over 20 years. However, in the Poore/Nemecek logic (as is also common in IPCC models) the animal protein products are burdened with these additional GHG emissions forever. Instead, they should have paid for the one time release within 20 years, and then their GHG emissions burden be reduced accordingly. The even more methodologically sound way would be to amortize the stock change over the whole period of the condition of being deforested, which might well be thousands of years. At the very least, it should be amortized over 100 years to be consistent with the logic by which methane climate impact is converted into $CO^2$ equivalents. This would immediately reduce the burden from land use by a factor of 80%, by using appropriate accounting.

The second methodological problem is more serious. Why should deforestation be assigned to agriculture and food production at all? There is an assumption that if there were less animal protein production in the world, then there would be less need for agricultural production, and accordingly less pressure to deforest lands.

This is a doubtful assumption. There would be no need for any additional deforestation in the world, if the existing agricultural lands were properly utilized with current state-of-the-art technologies (see Part I of this Quo Vadis Meat 2050 series). The reason why forests are being cleared is the weakness of legal and social institutions in the concerned tropical countries, combined with corruption and crime. These are compounded by endemic poverty and disenfranchisement in the rural communities. The empirical evidence points in the other direction: the poorer and less technologized a country is, the more deforestation and improper land use are prevalent. The more productive a country is, with a high value-added agricultural production system operating, the less deforestation occurs. In wealthy industrialized countries, forest areas are typically growing. The assumption that more demand for feed and pasture leads to more virgin land being cleared runs counter to agronomic economics and factual evidence.

The evidence is for instance collected by an undated, but presumedly recent report, called *Drivers of Deforestation*, published by the UK government as an international review of the REDD+ initiative (Reducing Emissions from Deforestation and Forest Degradation).[21] On page 13 this report explains:

[21] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/65505/6316-drivers-deforestation-report.pdf

*An analysis of the underlying drivers, drawing largely on 31 national REDD+ R-PPs, reveals that countries identify weak forest sector governance and institutions, including conflicting policies beyond the forest sector, and illegal activity (related to weak enforcement), as critical underlying drivers of deforestation and degradation (93% of countries). Population growth is the next most commonly reported underlying driver (51%), followed by poverty (48%) and insecure tenure (48%). 41% of countries explicitly mention international and market forces, particularly commodity markets, prices, and foreign direct investment as key underlying drivers. Some countries that reference agricultural export commodities as direct drivers of deforestation do not make the linkage to international and market forces as underlying drivers. The contrast between findings of scientific and other studies and what is reported by countries, emphasizes the fact that there is a need for more robust and comprehensive information about underlying drivers of deforestation and degradation.*

Given their own facts and analysis, it is a mystery how the authors of this report declare in the executive summary that 80% of the deforestation is due to agriculture. The summary number of 80% is often quoted in other reports or popular media, page 13 is not.

From an agronomic economics perspective, a drastic reduction in demand for agricultural production will lead to a global reduction in agricultural land values. This will make high productivity investments comparatively less attractive and less possible, and instead make the clearing of virgin land comparatively more attractive and more viable. It will also create more poverty in disenfranchised population groups whose means of living depend on clearing forests, and likely weaken the institutional systems even more. An aggregate reduction of global animal protein production could therefore lead to the opposite: even more deforestation.

An analysis by a German/Korean group of researchers published in February 2019 confirmed exactly such findings. Reducing meat consumption in Europe would not save any rain forest. If all of the European Union reduced meat and dairy consumption by 50%, this would create economic damage of USD 186 billion per year in the EU alone. The impact on global agriculture, and and especially the destitute poor, would be potentially disastrous (study available only in German).[22]

Conclusion: The man-made emissions of GHG from land use changes, particularly deforestation, are real. However, their amortization over only 20 years is inconsistent and illogical. More importantly, the assumption that the increase of agricultural production demand is directly related to an increase of agricultural land, is wrong and unfounded. The increase of agricultural land is due to social factors such as weak institutions, crime, corruption and structural rural poverty. In the event of a reduction of animal protein production, the pressure to expand the amount of agricultural land at the expense of existing forests might actually increase.

### 4.4 The pasture sequestration controversy

While there is no doubt that ruminants emit methane gas (almost all via eructation), what is not taken into account is that the soils on which these ruminants are grazing can also be sequestering methane gas, due to the grazing action. For instance the methodology report of FAO 2013, page xvi, states:

*Due to the lack of globally validated model and databases, sequestration and losses of soil C arising from pasture management could not be included in the assessment but can be significant.*

In other words, potentially significant factors in the life cycle analysis are not considered, or the data for them are not available, or both. Yet, this large and significant uncertainty is not reflected in what are presented as unambiguous facts of livestock harming the climate.

The way in which Poore/Nemecek 2018 treat the subject is also telling. On page 18 of their submission version to the journal *Science* (the version available on Poore's website) it says:

*Improved pasture management can temporarily sequester carbon, but it reduces life-cycle ruminant emissions by a maximum of 22%, with greater sequestration requiring more land.*

[22] Auswirkungen einer rein pflanzlichen Ernährung, Michael Schmitz, Institut für Agribusiness, Universität Gießen, Februar 2019, http://www.zdg-online.de/presse/detailansicht/?user_zdgdocs_pi2[entry]=956&user_zdgdocs_pi2[file]=M.Schmitz-Globale_Auswirkungen_einer_rein_pflanzlichen_Ernaehrung-2018_01.pdf

Acknowledging a maximum of 22%, Poore/Nemecek then proceed to set the value at 0 for their calculations. They reference the information maximum 22% to the above mentioned IPCC 2014 report, chapter 11. However, in IPCC 2014 this value is only mentioned as part of a table on page 860, and receives no further explanation. Moreover, in that table it is a MINIMUM of 22% with a maximum of 30%. However, this information is neither valuable nor useful, since it is referenced to the source of Kriegler et al published in 2013. Kriegler 2013 focused on an entirely different question. His paper's abstract reads:[23]

*This article presents the synthesis of results from the Stanford Energy Modeling Forum Study 27, an inter-comparison of 18 energy-economy and integrated assessment models. The study investigated the importance of individual mitigation options such as energy intensity improvements, carbon capture and storage (CCS), nuclear power, solar and wind power and bioenergy for climate mitigation.*

One looks in vain for an explanation of the 22% to 30% range in Kriegler 2013, because this article is a synthesis report of:

*Eighteen global energy-economy and integrated assessment models participating in the EMF27 study, originating from the USA (GCAM, FARM, MERGE, Phoenix), Canada (EC-IAM, TIAMWORLD, which is now used globally), the European Union (IMACLIM, IMAGE, MESSAGE, POLES, REMIND, WITCH), Japan (AIM-Enduse, BET, DNE21+, GRAPE), India (GCAMIIM) and the OECD (ENV-Linkages). Further details on these models can be found in the Supplementary Online Material (SOM) [only available to authorized users]. The models differ in numerous ways including their sectoral coverage, solution algorithm, representation of GHG emissions, energy demand and supply sectors, baseline assumptions and assumptions about techno-economic parameters. The large ensemble of models permits us to explore ranges of outcomes reflecting both structural as well as parametric uncertainties.*

As far as can be told from what is publicly accessible on any one of these 18 models, methane sequestration in soils due to grazing was not part of any of the investigations, and carbon sequestration in soil was only marginally dealt with. As the name of the exercise states, the EMF 27 metamodeling project was concerned with the energy and transport sectors, not with cattle.

The question that needs to be considered for our purposes is whether methanotrophic bacteria are stimulated in the soil by the grazing action of the ruminants. These bacteria feed on methane and convert it into protein-rich biomass, which then becomes part of the food-chain. This is not a temporary effect, but permanent sequestration in a biological cycle. In particular, it removes the highly climate-active methane from the atmosphere. It is then not appropriate to consider only one part of this cycle, the ruminant's eructation part, and count it towards GHG emissions, as the IPCC or FAO do.

Even from a logical angle, there should be a natural compensation mechanism to ruminant's enteric fermentation action. Ruminants have been roaming the wilds in large numbers for millions of years long before *Homo sapiens* stepped onto the scene. If these ruminants were a net-methane emitter to the atmosphere, on the scale as calculated by IPCC or Poore/Nemecek, then they alone would have been cooking the planet long before *Homo sapiens* received their chance to do so.

How significant could the factor of pasture sequestration due to methanotrophic bacteria be? During the 1990s a number of scientists studied and modelled the methane emissions of some types of insects, for instance termites or cockroaches. These animals are known to generate large amounts of methane. So they measured them under laboratory conditions, and multiplied the results with the estimated biomass of their prevalence, basically the same method with which ruminant emissions today are estimated. This modelling resulted in some implausibly high numbers of methane emissions. For instance in one study in 1994, researchers estimated that the four insect classes of Diplopoda, Blattidae, Isoptera and Scarabaeidae might be generating up to 320 teragrams of methane per year in tropical and subtropical regions.[24]

[23] The role of technology for achieving climate policy objectives: overview of the EMF 27 study on global technology and climate policy strategies; Elmar Kriegler & John P. Weyant & Geoffrey J. Blanford & Volker Krey & Leon Clarke & Jae Edmonds & Allen Fawcett & Gunnar Luderer & Keywan Riahi & Richard Richels & Steven K. Rose & Massimo Tavoni & Detlef P. van Vuuren; in Climatic Change, DOI 10.1007/s10584-013-0953-7
Downloadable at: https://www.pik-potsdam.de/research/climate-impacts-and-vulnerabilities/projects/project-pages/world-bank-report/publications/emf27-si-kriegler-ooo-cc14.pdf

[24] JOHANNES H. P. HACKSTEIN AND CLAUDIUS K. STUMM: Methane production in terrestrial arthropods, in Proc. Nati. Acad. Sci. USA Vol. 91, pp. 5441-5445, June 1994

To put this into perspective, it is currently assumed that the total amount of global methane emissions, from natural and manmade sources, is 558 teragrams (exhibit 11). All of agriculture and waste is estimated to emit a median estimate of 188 teragrams. It would be implausible that just four insect classes alone would be emitting 320 teragrams of methane per year. Accordingly, further investigation has revealed that in those areas where these insects are living and emitting methane, there is also heightened methanotrophic bacteria activity in the soil, which consumes this methane. Therefore the net emissions of these insects to the atmosphere are far lower to almost non-existent. In publications in the 1990s termites are usually listed as a separate source of methane emissions. In more recent publications, since the 2010s, they do not feature anymore.

The same effect could also apply to cattle pasture grazing. Not enough research has been undertaken to understand the picture, but what little has been done points towards the methane emissions being compensated. For instance, in Australia, Mark Adams, Professor of Bioscience and Innovation of the Swinburne University of Technology, made some calculations in 2009. On grazing land in the Snowy Mountains, methanotrophic activity would sequester 50% more methane per hectare than the cows that are grazing on it would be emitting. Thus, these pastures would be climate-positive.[25] However, Prof Adams never followed up on his calculations.

A Chinese research group under Wang *et al* did intensive investigations in the Chinese highlands, published in 2014, where they measured and modelled the net methane emissions of different grazing systems. Several systems were able to achieve positive net sequestrations, thus being climate-positive.[26]

Another Chinese research group under Liu et al came to similar results, published in 2017.[27]

There is also a Russian research group under Sabrekov et al, which yielded encouraging results for Siberian grazing systems, published in 2016.[28]

An Austrian research group investigated Alpine meadows, stating that grazing increased the methanotrophic activity, though they did not provide numbers.[29]

The above cited investigations do not constitute sufficient proof that cattle grazing systems are on the whole climate-neutral or even climate-positive. For instance, the above cited studies concern themselves with relatively wet highlands. Results for dry lowlands are likely to be different. There are also different classes of methanotrophic bacteria with widely different metabolic rates, and different grazing patterns arrive at different rates as well. The interactive cattle ecosystem of pasture, feed, cattle metabolism, soil chemistry, cattle intestinal microbial population, manure deposition and atmospheric chemistry is a complex system, where the interactions are not sufficiently understood. The methane emissions of the individual animal represent only one of the many interactions in that system. It is quite possible that a similar net scenario as with the termites and cockroaches applies. There is enough evidence to suggest that this budget item cannot be ignored.

All of the above only applies to cattle in grazing systems. Cattle that are kept in barns and fed with feed produced from far away will not have compensating methanotrophic activity in soil, due to the absence of their grazing action. However, the barn cattle are not those where the methane problem is concentrated. Thanks to their high productivity, their GHG emissions per 100 gram protein are

[25] http://adf.farmonline.com.au/news/nationalrural/agribusiness/general-news/ets-lifeline-soils-capable-of-absorbing-cattle-methane/1612492.aspx; or search for the headline: soils capable of absorbing cattle methane mark adams.

[26] Wang, C., Han, G., Wang, S., Zhai, X., Brown, J., Havstad, K. M., Ma, X., Wilkes, A., Zhao, M., Tang, S., Zhou, P., Jiang, Y., Lu, T., Wang, Z., … Li, Z. (2014). Sound management may sequester methane in grazed rangeland ecosystems. Scientific reports, 4, 4444. doi:10.1038/srep04444

[27] Liu, Y., Yan, C., Matthew, C., Wood, B., & Hou, F. (2017). Key sources and seasonal dynamics of greenhouse gas fluxes from yak grazing systems on the Qinghai-Tibetan Plateau. Scientific reports, 7, 40857. doi:10.1038/srep40857

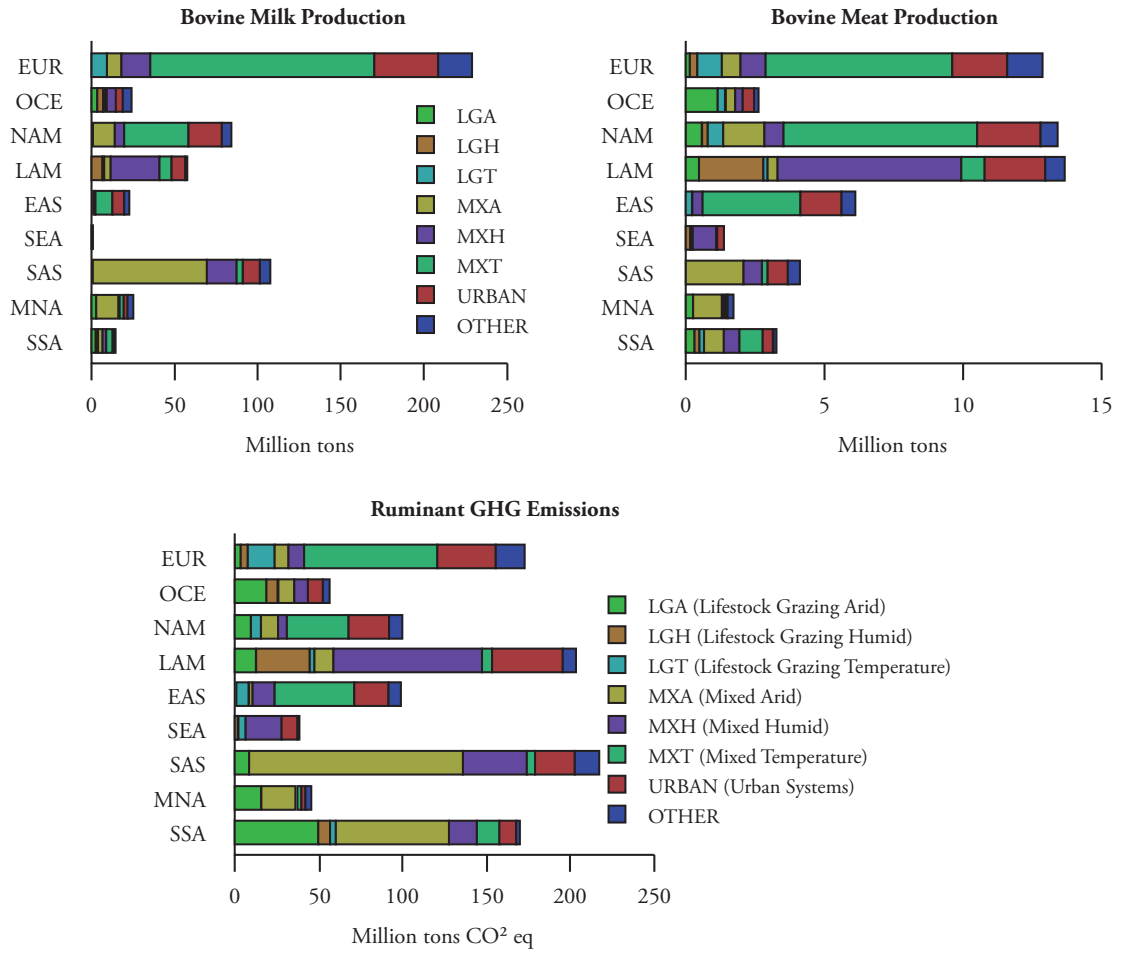
[28] A process-based model of methane consumption by upland soils, A F Sabrekov1,2,3,8, M V Glagolev1,2,3,4,8, P K Alekseychik5, B A Smolentsev6, I E Terentieva1, L A Krivenok2,4 and S S Maksyutov7 Published 8 July 2016 • Environmental Research Letters, Volume 11, Number 7

[29] Grazing affects methanotroph activity and diversity in an alpine meadow soil; Guy C. J. Abell,*† Nancy Stralis-Pavese, Angela Sessitsch and Levente Bodrossy, Austrian Research Centers, Department of Bioresources, A-2444 Seibersdorf, Austria. Environmental Microbiology Reports (2009) 1(5), 457–465 doi:10.1111/j.1758-2229.2009.00078

relatively low. Referring back to the publication of Herrero et al 2013, the numbers show that European and North American high productivity cattle produce around 50% of the global meat and dairy output but generate only 20% of the GHG emissions. The other regions, generating 80% of the GHG emissions, are also those where grazing systems are more prevalent. The Herrero article cannot be disaggregated in this particular way, but it is thinkable that overcompensation of methanotrophic activity in the grazing systems could also cover the 20% of the GHG emissions by the barned high productivity cows of Europe and North America.

Conclusion: Ruminants eruct methane and the amount that they produce can be fairly well established. However, ruminants also graze the soils and interact with the texture and structure of the grass biosphere. There is solid evidence that this grazing action leads to substantial stimulation of methanotrophic bacteria, which consume methane and thus remove it from the atmosphere. On the whole, this methane cycle is not sufficiently investigated to state with firmness how much compensation is going on. However, logic suggests that the cycle should balance, at least as far as grazing systems are concerned, and possibly for the whole cattle sector as well. Without such natural compensation systems, the rates at which ruminants are assumed to contribute to climate change within only a few decades, would have made long term climate stability impossible in the *pre-Homo-sapiens* millions of years of time when there were large herds of ruminants roaming nature. The evidence from termites and cockroaches points in the same direction of a natural compensation system.

**Exhibit 8:** Productivity and GHG Emissions




*Source: PNAS, Herrero et al., 2013*

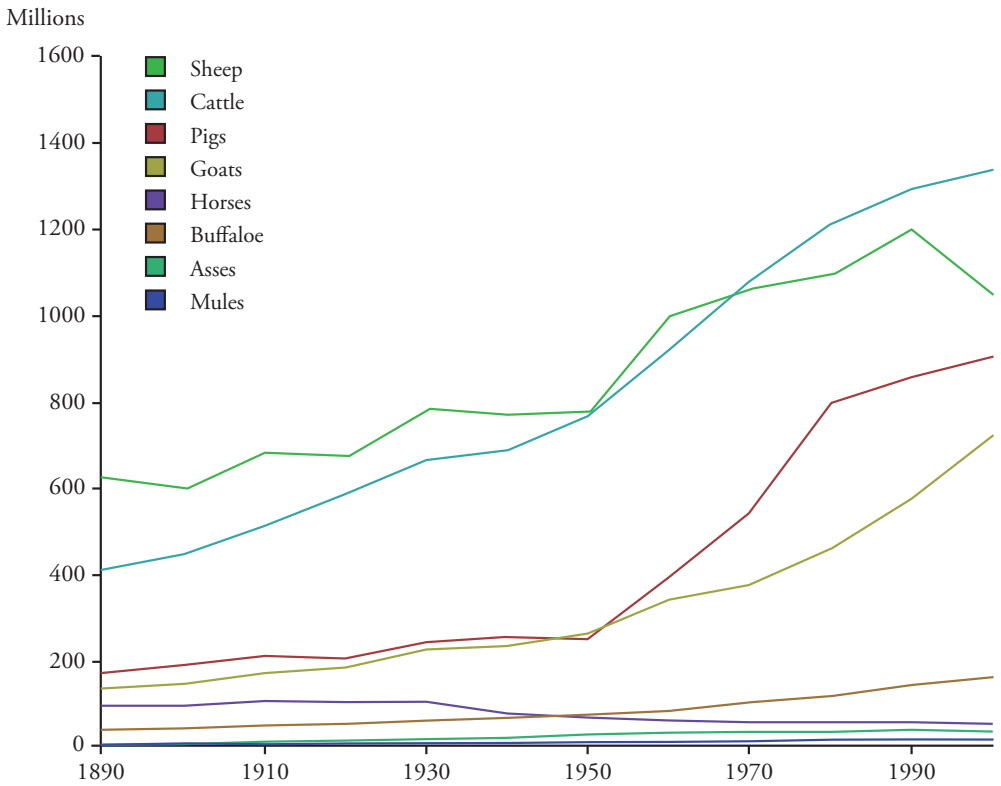
### 4.5 The methane cycle and natural state controversy

It is well understood that climate change is a natural phenomenon of planet Earth. There have been multiple ice ages before, and Antarctica was several times a green continent with lush forests during warm ages. The worry is that man-made GHG emissions since the industrial revolution are causing high speed climate change, which will trigger a collapse of the natural eco-system, which is already stressed to the limit by *Homo sapiens*' civilizational activity. It is the speed that is the problem, and the dependence of humanity on a functioning and stable ecosphere. For instance, most animals and plants would not care about the ocean levels, but human cities built along the coast lines are uniquely vulnerable to even small changes in them.

The large expansion of a domesticated ruminant herd in the course of the past 130 years can be counted as a man-made effect. According to Hyde, a history database of the global environment sponsored by the Netherlands Environmental Assessment Agency,[30] there were around 500 million cattle around in the year 1900 (including buffalo) and 1.5 billion of them by the year 2000. The population of sheep grew from 625 million to 1050 million, and goats grew from 137 million to 722 million in that period of time. These animals exist because of human activity, and therefore eruct their methane into the atmosphere because of humans.

However, there is another man-made effect that needs to be counted against this expansion. How many animals, of naturally occurring ungulates, would be inhabiting the biospheres that are now occupied by domesticated ruminants or humans, and would therefore be natural emitters of methane? For instance, in the US prairies, there was an original herd of 50 million American bison with roughly the same biomass as the US cattle herd of today, until they were shot out of existence in the 1800s. The same is true for the Eurasian wisents and aurochs: how many of them were roaming the vast grasslands of the Eurasian steppe and are not today? Today's 1.5 million hectares of African Serengeti is home to about 3.2 million ungulates. Today's Eurasian steppe extends across 400 million hectares, and might have been twice as large before human impact since antiquity. Can we assume then that before humans took over the Eurasian continent there was a herd of ungulates of around 1 billion animals on its steppe alone?

**Exhibit 9:** Number of Domesticated Animals Worldwide




*Source: Kees Klein Goldewijk, Regional Livestock Estimates, 2005*

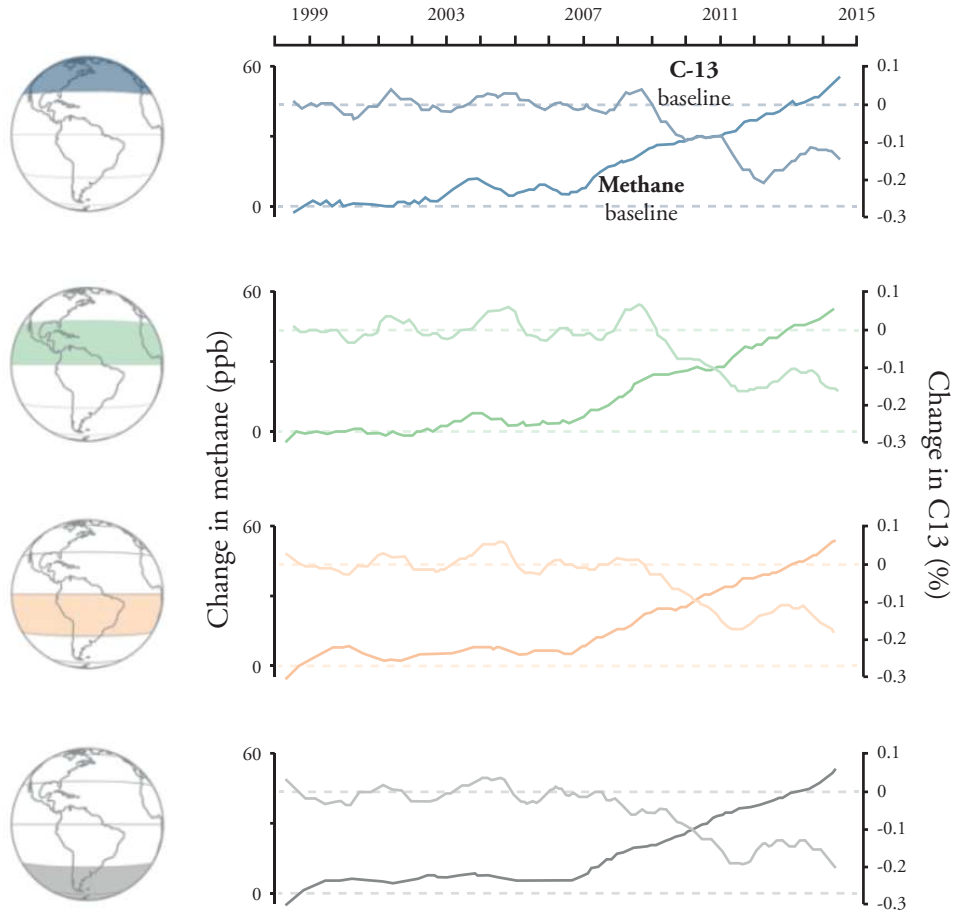
[30] https://themasites.pbl.nl/tridion/en/themasites/hyde/landusedata/livestock/index-2.html

If these animals were part of the pre-human natural cycle, and today do not exist because of human impact, then their GHG emission budget would need to be deducted from today's global herd of domesticated ruminants. Unless, of course, there was a natural compensation mechanism that sequestered their methane emissions. But then that natural compensation mechanism would also need to be active under today's circumstances, which is the controversy dealt with in the previous section.

Possibly the most prominent scientific group that attempts to understand the global methane cycle is the Global Carbon Project. It published its most recent report on the methane cycle in December 2016. Its global methane budget illustration is shown in Exhibit 11. In contrast to the FAO 2013 Report, this research group clearly shows the large range of estimates. For global agriculture, the median estimate is an emission of 188 teragrams of methane per year, which is 57% of the total manmade methane emissions, and 34% of the total emissions including natural sources. The range is given to be between 115 and 243 teragrams for agriculture. Such a large range makes the median number practically meaningless. For instance, the corresponding estimate from Herrero 2013 for the global budget of enteric fermentation is around 70 teragrams per year. This might be either two thirds or one third of the total, depending on what the total is.

**Exhibit 10:** Global Methane Emissions

**Methane levels are rising, but the relative amount of carbon-13 ("heavy" carbon) is falling**




*Source: NDAA Climate.gov, Nisbet et al., 2016*

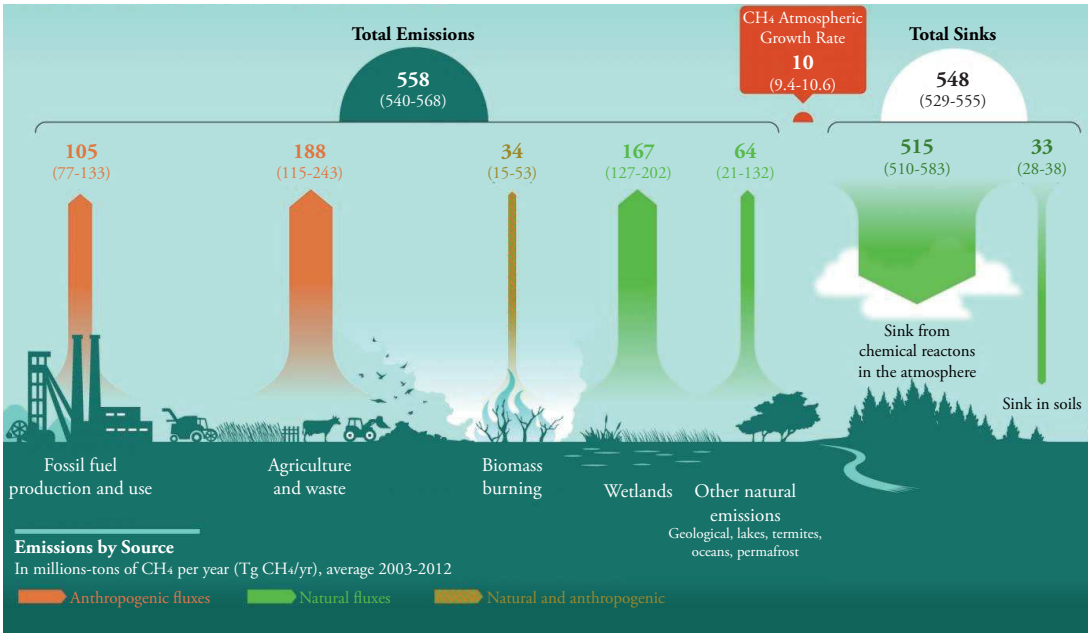
There are more problems with the methane budget. Science has precise measurements of where methane is located in the atmosphere, and in what season of each year. The pictures and videos are publicly accessible at the European Space Agency.[31] The resulting pictures show, with a high degree of certainty, that the atmosphere does not accumulate methane in those areas where lots of cattle are being kept. Exhibit 12 shows the concentration of methane and compares it with the concentration of cattle. Clearly visible are the high methane concentrations where, in South China, the rice fields dominate agriculture. Rice fields are assumed to contribute between 23 and 40 teragrams of methane per year.[32]

Clearly visible also are the large methane emissions of the tropical belts in West Africa and the Amazon, resulting from the natural biological decomposition processes. Also clearly visible are the leaking gas pipelines in Russia. What cannot be seen in the methane concentrations is where the assumedly 70–100 teragrams of methane emissions from cattle might be correlated with where the cattle are present. Typical livestock concentration areas such as southern South America, the Ethiopian highlands, Australia or New Zealand do not correspond to any methane concentration. Dense livestock presence in India or Europe does not seem to create more methane concentration in these regions that would not be better explainable by fuel consumption. A correlation analysis would fail completely. This is further support to the proposal that enteric fermentation of cattle is naturally compensated by methanotrophic bacteria or even other mechanisms.

There is a further problem with the methane budget that also demonstrates that enteric fermentation cannot be as decisive as it is proclaimed to be. Today's methane levels in the atmosphere are around 1800 ppb, while for the past 100,000 years the levels fluctuated between only 400 and 700 ppb. Thus, today we are at more than three times the historic levels. But these rises are not continuous and do not correlate with the stocking levels of domesticated ruminants.

Between the years 1999 and 2007, atmospheric methane levels were stable across all global regions. From 2007 they have been rising steeply. At the same time, methane that is rich in the C13 isotope has been decreasing steeply. This is significant, because the C13 isotope is that most linked to fuel-based emissions. One good candidate for this fall is the widespread repair of Russian gas pipelines.

**Exhibit 11:** Global Methane Budget




*Source: Global Carbon Project*

[31] Earth System Science Data, DOI:10.5194/essd-8-697-2016, 697–751, 2016, p. 705
[32] https://www.csmonitor.com/Environment/2016/1212/Climate-change-Why-are-global-methane-levels-spiking

But what would account for the correspondingly steep rise of the biologically created methane, be it natural or through agriculture? There is no corresponding sudden rise in either livestock or rice fields to explain this. The scientists are still at a loss to gain an understanding. Rob Jackson of Stanford University and one of the co-authors of the Methane Global Balance project says:[33]

*Unlike carbon dioxide, where we have well described power plants, almost everything in the global methane budget is diffuse. From cows to wetlands to rice paddies, the methane cycle is harder.*

### 4.6 Overall conclusion to the 'meat is bad for the climate' narrative

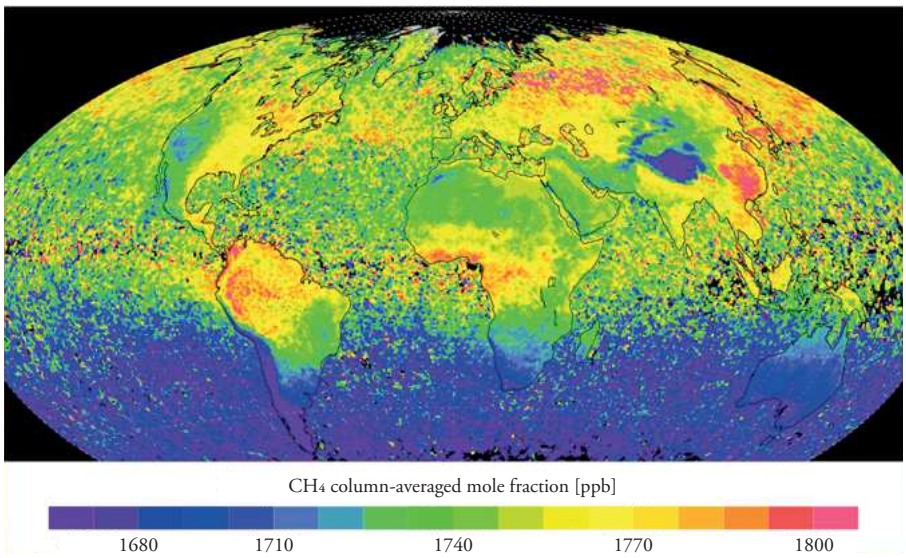
Given all this uncertainty, is it valid to take either regulatory or voluntary action to reduce livestock products in the global diets, and in particular cattle products, in order to reduce GHG emissions? In conditions of uncertainty, one might claim that the precautionary principle suggests action before conclusive evidence has been achieved, if the possible outcomes are too dire (for instance global warming). But what if the precautionary actions a have the opposite effect? With the current state of knowledge it cannot be ruled out that the net emissions of methane of the cattle bio-system are actually climate-positive. Given the absence of a correlation of regional livestock presence and regional methane concentration, it is more likely that the cattle bio-system is a net sink for methane, rather than a net emitter. It also cannot be ruled out that current mitigation actions, with good intentions but based on weak evidence, have counter-productive effects: what if dietary changes lead to more rice consumption, where there is no ambiguity of methane-emissions?

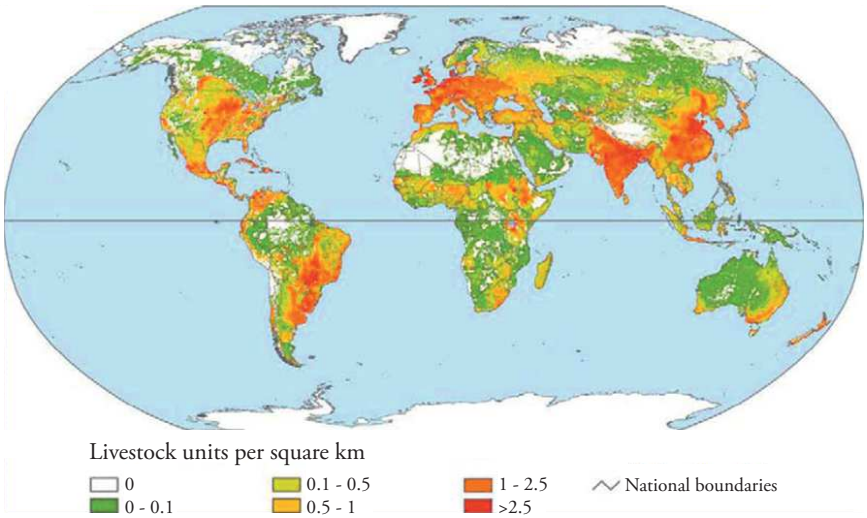
What if a large scale dietary shift away from dairy and meat products creates a public health crisis because the population does not know how to maintain a complete nutrient balance on a vegan basis? What if a collapse in agricultural land prices due to non-utilized pastures and arable lands causes a global financial crisis and lasting damage to the productivity growth of the agricultural industry, and with it more environmental damage such as from increased rates of deforestation, bad water management and non-sustainable soil treatment?

The precautionary principle should suggest to conduct more bias-free science.

[33] https://www.csmonitor.com/Environment/2016/1212/Climate-change-Why-are-global-methane-levels-spiking

**Exhibit 12:** Methane and Cattle Concentration




*Source: Envisat (2003-05), FAO (2006)*

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