Discussion document being compiled for Climate Friendly Bradford on Avon (CFBoA). (To be completed.) Ros Edwards, Lead for the CFBoA Sustainable Food and Drink Group 30.07.2019

Draft (Vs 1.3) of

Confounding Factors in discussions about what we should eat to decrease climate change and ensure sustainable food for all, now and in the future.

What gets in the way of communication and clarity around the issues?

Sections:

1) **The complexity of the issues.**

2) The way that the carbon footprint (CFP) of food is measured.

This issue confounds all. It seems that the measures used to assess the carbon footprint almost always show that more intensively produced food is associated with a lower carbon footprint, which leads to a strong suspicion that many factors are not being taken into account.

Most carbon footprinting tools do not include assessment of the very important gains to, and losses from, the soil of greenhouse gases (GHGs) resulting from food production, because it is complicated and very variable. Although gradually more factors are being included into some tools, most still do not reflect food production cycles that best maintain living, fertile soils, capable of producing nutritious food sustainably into the future, and capable of sequestering carbon, supporting biodiversity, improving soil structure and filtration of water, and resilience to climate extremes such as drought and flooding. Often water use in areas of water stress is not included. Different methods of producing the same food may have very different environmental impacts, however that is not usually presented to us through these measures. The complicated journey that different foods may take to reach our table clearly cannot be reflected in these measures either.

"LCA (Life Cycle Assessment) was originally applied to analyse industrial process chains" according to the UN's Food and Agriculture Association (FAO), but has been adapted to assess the environmental impacts of agriculture (Ref 1). The FAO indicates that significant challenges arise when these measures are applied to complex systems such as agriculture and the food chain. "The application of LCA to agricultural systems is often complicated by the multiple-output nature of production, as major products are usually accompanied by the joint production of by-products."

Milk and its by-products are given a low carbon footprint compared to meat. This gives the impression that dairy products can be produced in isolation. However, dairy beef and veal, from surplus calves and culled cows, are natural and inevitable co-products of the dairy system. This separation of co-products in carbon footprinting measures, by means of allocations and substitutions, also applies to other agricultural products leading to distortions of perception, which may mislead consumer choices and public policy. The way that "Allocations" and "Substitutions" may be made in the measurement of the carbon footprint is included in an extract below from the Food Climate Research Network (FCRN) on the methods of measuring CFP in Ref 2.

The FCRN, which is based at Oxford University, says that "LCA is an extremely useful tool but cannot by itself indicate the sustainability of a product or process."

Another indicator that the carbon footprinting (CFP) approach may not be all it is cracked up to be in helping us determine what are the most helpful ways forward to reducing climate change comes from the findings of Kalbar et al in 2017 when asking "Can carbon footprint serve as proxy of the environmental burden from urban consumption patterns?" They conclude "that while CFP can be a good indicator of the environmental burden associated with specific activities, this is not the case for more complex activities (such as consumption patterns related to urban life styles). This conclusion discourages the use of CFP as a sustainability measure in relation to regulation of private or public consumption." (Ref 3). This would tally with the reactions of some members of Climate Friendly Bradford on Avon on using a carbon calculator.

As many CFP tools use different inclusions/ exclusions and ongoing changes to methodology, comparisons between research findings in meta-analyses is difficult; in addition, there are often high levels of uncertainty in some of the factors assessed in these complex biological domains.

The researchers of 'A Global Meta-Analysis of Grazing Impacts on Soil Health Indicators' recommend the development of consistent guidelines for soil health evaluation in grazing studies to allow for the grazing impacts on soil health to be quantitively compared in future meta-analyses. (2018, Ryan C. Byrnes et al, Ref 4)

The Carbon Cutting Toolkit is one of the few on-farm measuring tools which looks at soil carbon content (Ref 5). Becky Willson, Technical Specialist Resource Management, Rural Business School, Duchy College discussing soil carbon says it would be very helpful "if more clarity and comparability can be established through government recommendations on the method that is used to assess greenhouse gas emissions from farms. If all work to the same metrics then true comparisons (with all the associated caveats) would become possible. The most important business to benchmark with is your own as it is truly replicable. All farming systems and businesses are different and operate under different management and landscape constraints, as such, truly comparing businesses there will always be confounding factors. BUT it starts by all using the same metrics and using them as a basis for discussion."

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References:

1. Greenhouse Gas Emissions from the Dairy Sector A Life Cycle Assessment http://www.fao.org/docrep/012/k7930e/k7930e00.pdf (Extract)

The LCA method involves the systemic analysis of production systems, to account for all inputs and outputs associated with a specific product within a defined system boundary. The system boundary largely depends on the goal of the study. The reference unit that denotes the useful output of the production system is known as the functional unit, and it has a defined quantity and quality. The functional unit can be based on a defined quantity, such as 1 kg of product, alternatively it may be based on an attribute of a product or process, such as 1 kg of fat and protein corrected milk (FPCM). The application of LCA to agricultural systems is often complicated by the multiple-output nature of production, as major products are usually accompanied by the joint production of by-products. This requires appropriate partitioning of environmental impacts to each product from the system according to an allocation rule, which may be based on different criteria such as economic value, mass balances, product properties, etc.

2. Food Climate Research network (FCRN) https://www.foodsource.org.uk/21-lifecycle-assessment-lca-quantifies-environmental-impacts-cradle-grave-product

[Carbon footprint measurement]

Extracts –

The **functional unit** is the unit that is being studied.

LCAs [Life Cycle Analysis] for food products normally use weight of finished food products as the functional unit (e.g. 1 kg of pork), but also use units of area (for example, the environmental impact of wheat production in terms of hectares used) or nutritional units (for example, the environmental impact of producing 100g of protein from a food

product). The choice of functional unit could influence comparison between foods. For example, egg usually has a lower carbon footprint than poultry meat if the functional unit is 1 kg of product (egg or poultry meat) but if the functional unit is 1 kg of protein instead, the carbon footprint is more similar between the two as eggs only contain 12% of protein compared to 20% in meat.

The relative impacts of different products can change, depending on which functional unit is used.

How do we deal with the problem of allocating emissions to products?

a) **Avoid allocation altogether**
If possible it is preferable to avoid having to divide emissions between co-products by, for example, expanding the system boundaries to include all products produced in a dairy system in the functional unit. However, if the purpose of the study is to compare milk with some other beverage, emissions needs to be split between the milk and the meat.

b) **Substitution**
One way of handling this is to consider alternatives to the co-products on the global market based on the reasoning that when a co-product of a production system enters the market the production of some other product with the same function can be 'avoided'. For example, the beef produced in the dairy system would avoid production of other beef meat e.g. from a suckler cow system or meat from pork or poultry. The emissions from the production of milk is then calculated as the total emissions from the dairy system minus the emissions from the production of the alternative 'avoided' product, in this case the beef.

c) **Allocate based on physical relationships (e.g. mass or energy) or economic relationships**
Another simple way of doing this is to allocate by mass or economic value. For example, if an economic allocation method is used, then the relative economic value of the co-products is used as the basis for allocating impacts – e.g. the relative value on the market of milk and meat. The precise impacts will vary as the market prices fluctuate.

3. https://www.sciencedirect.com/science/article/pii/S1470160X16306

Can carbon footprint serve as proxy of the environmental burden from urban consumption patterns? Ecological Indicators Publisher: Elsevier March 2017 https://doi.org/10.1016/j.ecolind.2016.11.022

4. Pradip P. Kalbar, Morten Birkved, Subhankar Karmakar, Simon Elsborg Nygaard, Michael Hauschild A Global Meta-Analysis of Grazing Impacts on Soil Health Indicators Ryan C. Byrnes, Danny J. Eastburn, Kenneth W. Tate, and Leslie M. Roche* Pub April 5th 2018 Journal of Environmental Quality NCBI

doi: 10.2134/jeq2017.08.0313

5. https://www.farmcarbontoolkit.org.uk/

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3) Difficulty squaring the circle

There is a discernible tension in government and academic documents between "the evidence" that generally intensive food production is shown to have a lower carbon footprint, as measured by the tools presently used, and "the knowledge" that this is not the whole picture. Policies and guidelines based on the dimensions that are measurable, whilst leaving out, or treating separately, the dimensions that are not easily measurable, although immeasurably important, lead to a vision which lacks integration, with the potential to distort and misdirect the lived reality and best outcomes.

So, the Agriculture Bill advocates intensive agriculture and increased productivity (even though there are already enough calories produced globally to feed the projected 2050 world population and one third is wasted), and rewards "public goods", such as habitat for wildlife, around the edges of food production. The Soil Association has raised concern that the health of the soil (and its ability to store carbon) is not included as a "public good" in the Bill and agroecology is not mentioned (at least prior to Committee stage amendments being passed). Defra says that "The Government has demonstrated its commitment to healthy soils through setting a target in the 25-Year Environment Plan to manage all soils sustainably by 2030."

The endorsement of "the efficiencies of scale" and intensive arable, dairy, other livestock and poultry production by the carbon footprinting tools works well in the interests of specialised farming, big businesses and the national and international corporations who now dominate the global food chain. It also works well for government, who can look forward to very substantial revenue by incentivising a high-tech farming future, with all the scientific development and manufacturing infrastructure and product potential that this involves; along with the keen expectation of that technology, such as genetically edited foods, becoming key UK export products. However, the drive towards intensification and some of the high-tech approaches do not reflect the wide benefits to the environment and people of agroecological food production (such as organic). There is less potential for significant tax revenues from an agroecological approach to food production and there is a serious lack of funding for research into natural solutions in agriculture; whereas there is a huge industry-funded research drive into technological solutions, with the next fix always around the corner.

Sustainable intensification is advocated as a "more for less" practice. It can be used to describe a wide range of different practices, some very positive, although many less so. In most cases increased productivity will give a lower carbon footprint: breeding animals to produce more and more milk, or more meat; keeping animals and poultry in a restricted environment leading to faster conversion of feed into weight gain; in US and Canada, for example, routine hormone and antibiotic use in cattle can lead to faster growth, more milk production and so on; all lead to faster production of more food and use of less land. Crop yields may also be higher per land area through modifications, agrochemicals, irrigation etc some of which may have environmental (or health) downsides. However, CFP is used to justify these practices in terms of efficiency of decreased land and input use per unit of output, in relationship to GHG emissions (as measured!). Indeed, it is clear that CFP is now a key <u>driver</u> of intensification in farming and food production, with wider environmental, animal welfare and reduction of animal breed and food plant variety implications.

As consumers, we may have swallowed the carbon footprinting idea whole and try to tailor our food buying choices accordingly, however we are not being given the whole picture. So public and private debates and discussions become (often unwittingly) mired in the anomalies which the shortcomings of CFP introduce into the search for a best environmental way forward.

The EAT-*Lancet* commission recommendations (2019, Ref 6, p. 10) reflect this Catch 22 scenario. On the one hand, in their text, there is positive advice to "support environmentally sustainable and socially responsible farming" by voting "with every plate". They recommend, for example, supporting "Regenerative farming practices: As livestock are central to sustainable farming, sourcing meat from farmers that practice regenerative agriculture can support the fight against climate change. This type of farming contributes to carbon storage in the soil, keeps water away from pollutants, and provides room for local biodiversity to flourish." On the other hand, their "planetary health plate" does not sit well with these earlier statements. They advocate high consumption levels of legumes [which in the UK would be mainly imported with unknown impacts on land use, environmental and societal impacts abroad and may increase prices in staple foods for the world's poorest people], very low meat intake [the UK is able to produce high quality grass-fed meat at significantly higher levels than this report recommends, whilst still being in line with health guidelines for red meat intake], principally from poultry and pigs [which are monogastric and therefore produce less methane, but also are mainly in today's world produced in large, intensive systems and in the UK are the largest consumers of grains and concentrates, including soy]. The report emphasises that more fruit, veg and nuts should be eaten, as do the UN and other dietary guidelines. Although not highlighted in the media reporting, it also indicates that the "planetary health diet is flexible and recommends intake levels of different food groups that we can adapt to our local geography, culinary traditions and personal preference." At the same time (and not without self-contradiction), it refers to the challenge of converting countries with strong traditional food consumption patterns, such as Japan, to their planetary health diet.

Interestingly "The Commission acknowledges that food systems have environmental impacts along the entire supply chain from production to processing and retail, and furthermore reach beyond human and environmental health by also affecting society, culture, economy, and animal health and welfare. However, given the breadth and depth of each of these topics, it was necessary to place many important issues outside the scope of the Commission." There has been concern expressed about the nutritional adequacy of these EAT-*Lancet* dietary guidelines, as well as the environmental and societal impacts. The World Health Organisation has now withdrawn its support for the recommendations of this report (April 2019, Ref 7, 8).

Globally, intensively produced poultry and pigs are now the predominant meats consumed. In the UK, poultry and pigs consume more grain and concentrates (including soy) than our dairy and beef cattle combined (and our dairy cattle consume more than our beef cattle). Widespread crop harvest failures could therefore seriously impact the availability not only of our sources of plant sourced proteins (as well as other plant-based macro and micro-nutrients) but also protein from grain-dependent livestock and poultry. This is effectively putting all of our eggs into one basket (reliance on crops). Although animals can also be affected by extreme weather conditions, there are some severe weather conditions that may wipe out harvests, which grass-fed livestock may be well able to withstand, thus increasing our food security as long as these animals are not dependent on grains. Even after prolonged drought, grass has a remarkable ability to bounce back quickly with new growth once conditions become more favourable. Hay and silage crops are taken in late spring to early summer, to store as winter feed for animals, or in severe droughts to supplement summer forage. Our vegetables, fruit, grains and oilseeds are mainly cropped later in the year. The differing timing of the annual cycle means that grassland foods can therefore improve food security and resilience to extreme weather events within our food system. Meat and dairy produce provide not just proteins but also fats and important micro-nutrients, and can reduce our dependence on palm oil, and other oils produced from annual crops. From the grass grazing animals consume, the benefits that accrue are not just food, but clothing – reducing reliance on synthetics (which have a range of negative impacts on the environment and do not biodegrade) - and other by-products. Importantly, part of the food they consume is converted to dung, which enables crops to be grown without, or with reduced, use of artificial fertilisers (Defra); organic matter from animal dung and manure gives the land more resilience to drought and flooding and also increases biodiversity. However, the Eat-Lancet study, at the same time as making dietary recommendations based on carbon footprinting rather than whole farming and ecological systems and recommending more protein from granivores than herbivores, identifies grasslands for alternative possible uses, such as bioenergy, biodiversity or woodland.

By contrast, the IDDRI European study entitled Ten Years for Agroecology (TYFA) (2019, Ref 9), states that "Overall, the 'climate-centric' approach to agriculture-environment relations—and in particular grasslands and cattle production—that has gained prominence does not lend itself to considering these different dimensions. Conversely, the TYFA assumptions are multifunctional from the outset, and give equal priority and ambition to biodiversity conservation, climate mitigation and nutritional challenges." Different models for sustainable food production whilst mitigating climate change and reducing environmental impacts are examined. The TYFA scenario shows that "there is potential for phasing out pesticides while maintaining export capacity comparable to the current situation and, above all, while importing far less. It is possible to take an ambitious approach to biodiversity involving extensive herbivore systems and diversified cropping systems without synthetic inputs, while simultaneously reducing GHG emissions." "Livestock production declines by approximately 40% in tonnage and in calories, largely due to the decline in the production of granivores and of pigs in particular, but also of dairy products (-31% between 2010 and 2050) Overall, maintaining a certain production and therefore consumption of beef is largely the result of the assumptions regarding the conservation of grassland areas and the extensification of the associated dairy production. The fact that this dairy beef production in 2050 corresponds to the 2010 level of consumption is a coincidence, not a structural assumption of the diet" (p. 46 -7) Higher animal welfare means that dairy cows produce yearly calves over a longer life-span, so more dairy beef is produced relative to dairy produce. "Although the changes envisaged are substantial, they also respond to public health challenges and to widely expressed social expectations regarding healthier diets." It is well aligned with existing eating habits within the region to facilitate adoption of the recommendations.

"Main assumptions of the TYFA scenario:

Fertility management at the territorial level that depends on:

The phase-out of synthetic pesticides and the extensification of crops.

The adoption of healthier, more balanced diets according to nutritional recommendations.

Priority to human food, then animal feed, then non-food uses.

• The suspension of soybean/plant protein imports

• The reintroduction of legumes into crop rotation

• The re-territorialisation of livestock systems in cropland areas production - all year soil cover: organic agriculture as a reference.

The redeployment of natural grasslands across the European territory and the development of agro-ecological infrastructures [—hedges, trees, ponds, stony habitats favourable to insects — to cover 10% of cultivated land, in addition to the extensive grasslands that are the main component of these infrastructures.]

The extensification of livestock production (ruminants and granivores) and the limitation of feed/food competition, resulting in a significant reduction in granivore numbers and a moderate reduction in herbivore numbers.

• A reduction in the consumption of animal products and an increase in plant proteins

• An increase in fruit and vegetables”

The IDDRI study provides further evidence that an agroecological paradigm of farming and food production can feed the 2050 population well, whilst at the same time delivering widespread environmental benefits (Ref 10). This supports the findings and recommendations of the 4-year study by 400 scientists from different disciplines worldwide in 2008 by the IAASTD, which was commissioned by international organisations including the UN, the World Bank and the WHO (a report that was side-lined because it raised major concerns about genetic engineering techniques in food and farming – Ref 11). This report also advocated a rapid transition to an agroecological approach to farming globally.

Sir David Attenborough in the important BBC broadcast ‘Climate Change: The Facts’ on 8 April 2019 seemed to reflect recommendations of the emissions-led carbon footprinting process with regard to how we should change our food habits, rather than the IDDRI recommendations. One wonders if he or his team were aware of the IDDRI report, which has not had the same publicity machine behind it as EAT-Lancet. So, here too the dichotomy is evident: whilst recommending that people urgently reduce consumption of meat, “especially beef and lamb”, thereby inferring that the pig and chicken products, for example, are preferable, Sir David also said *except for traditionally raised animals*. However, most British lamb and beef are produced mainly from grassland products. (It is worth looking at the article ‘Reducing meat production and consumption: should the focus be on ruminants or monogastrics?’ Compassion in World Farming 2017. Ref 12). Sir David highlighted the huge problem of palm oil.

Palm oil is the most efficient plant-based fat, in terms of productivity per hectare and also comes from permanent planting rather than annual crops. And it is throughout our food system. But at what a cost!

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References:

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7. https://www.dailymail.co.uk/health/article-6907429/World-Health-Organization-pulls-support-controversial-planetary-health-diet.html
8. https://www.bmj.com/content/365/bmj.l1700.full
9. Poux, X., Aubert, P.-M ‘An agroecological Europe in 2050: multifunctional agriculture for healthy eating. Findings from the Ten Years For Agroecology (TYFA) modelling exercise’ (2018) Iddri-AScA, Study N°09/18, Paris, France, 74 p.
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10. Rebecca Smithers ‘European farms could grow green and still be able to feed population’ Wed 20 Feb 2019 The Guardian GNM
https://www.theguardian.com/environment/2019/feb/20/european-farms-could-grow-green-and-still-be-able-to-feed-population
11. https://www.globalagriculture.org/
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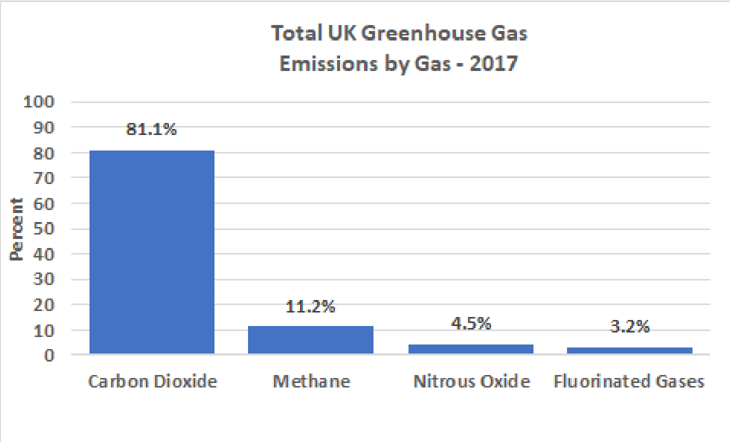
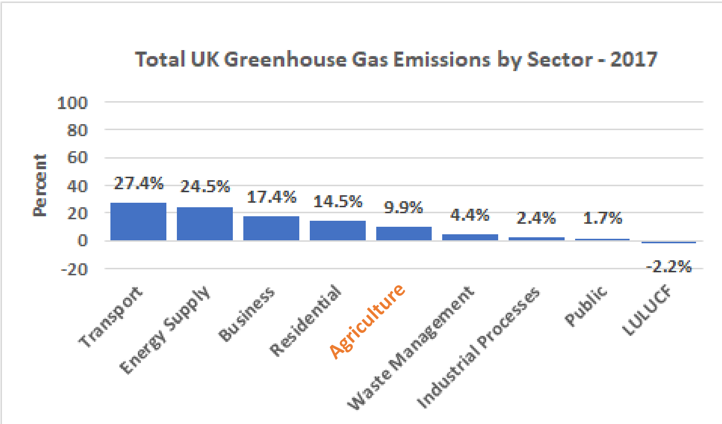
4) Emissions: getting things in perspective

The public discourse on what we should eat is considerably influenced by use of global and sometimes US statistics, and how statistics are presented. According to Defra "There are many challenges with making international comparisons due to differing farming systems, lack of comparable data and, in some instances, a lack of data." American films, such as Cowspiracy, seem to have had a powerful effect; however, an All Party Parliamentary Group in 2013 reported that in the UK the majority of our beef is mainly grass-fed (Ref 13) and our grasslands are naturally rain-fed (Ref 14).

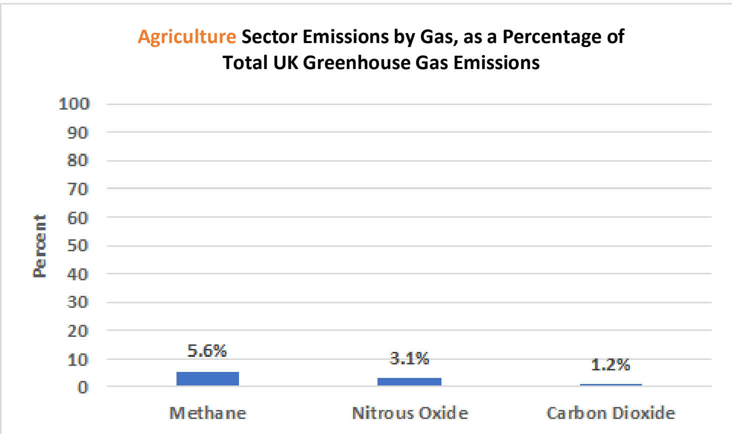
UK Greenhouse Gas (GHG) Emissions (2017 figures, published 2109, Ref 15). All gases are adjusted for Global Warming Potential to give carbon dioxide equivalence (CO2e) Many thanks to David Lindop who has kindly compiled the 3 graphs below for this document, based on the data in Ref 15.



Graph 1 Total UK emissions from all sectors are dominated by carbon dioxide (CO2) which accounts for 81.1%, mainly from fossil fuels. See graph 3 for CO2 due to agriculture. Total methane is 11.2 per cent of UK emissions, about half is from waste management and the energy supply, the other half is biogenic methane from agriculture. Nitrous oxide is 4.5 per cent of total.



Graph 2 The percentage of the total UK GHG emissions from different sectors: transport sector 27.4%; energy supply 24.5%; business 17.4%; residential 14.5%; agriculture 9.9%; waste management 4.4%; industrial processes 2.4%; the public sector 1.7%. Energy supply is not included in the emissions from industrial processes, but is in the public sector!



Graph 3 Agricultural emissions. Methane, mainly from enteric fermentation from cattle, accounts for just over half of the agricultural 9.9% total contribution to UK emissions. This is known as biogenic methane as it is derived from the plants eaten by animals and is part of the natural carbon cycle. Although it augments the warming effects of greenhouse gases, biogenic methane dissipates in the atmosphere and is reabsorbed within total about 10 years. It does not carry on accumulating and persisting in

the atmosphere indefinitely as do fossil fuel emissions – see more on biogenic methane below. There is a risk that the preoccupation with methane from cattle and other farm animals is distracting from the vital need to radically reduce the true climate changing fossil fuel emissions - from coal, oil and gas (petrol, diesel etc) - particularly total UK emissions from energy and transport, as well as from business, residential and other sectors - see graph 2 above. Nitrous oxide - 90% of which is related to nitrogen fertiliser (again fossil fuel based) application to agricultural soils - accounts for about a third of the UK agricultural emissions equating to 3.1% of total UK GHG emissions. The 1.2% of total UK emissions attributed to CO2 from agriculture is mainly for fuel for farm machinery.

The Land Use, Land Use Change and Forestry (LULUCF) sector acted as a net sink in 2017 (-9.9MtCO2e) so emissions were effectively negative. Forest Land, Grassland and Harvested Wood Products are net sinks of GHGs, whereas Cropland, Wetlands and Settlement categories are net sources.

The LULUCF sector has been a net GHG sink ever since 1990 and this is increasing. "The LULUCF sector is the only sector within the national greenhouse gas inventory to report net removals [of GHGs from the atmosphere]" (p.333). Only land use change is counted in these national statistics. Conversion of permanent grassland to cropland leads to huge and rapid losses of soil carbon stocks to the atmosphere and should be avoided; conversion of cropland to grassland leads to substantial gains in carbon stocks over a prolonged time frame.

For any particular land management practice a new equilibrium of soil carbon stocks will be reached (sometimes after many decades). In a state of consistent management, grasslands generally have considerably higher carbon stocks than crop lands, which may over time have lost very significant amounts of the soil carbon stocks and be 'running on low', sometimes with seriously depleted levels of organic matter. "Increases in inputs of fertiliser, manure and crop residues were found to increase soil carbon stocks of tillage land, but changes in the tillage regime from conventional tillage to reduced or zero tillage were found to have no significant effect in a UK context" (p.734).

Conversion to Settlements leads to a very high rate of soil carbon loss and the losses are even greater when grassland is converted than when arable land is converted to settlements.
(Quotes above from ukghgi-90-17_Annexes_Issue_2.pdf https://unfccc.int/sites/default/files/resource/gbr-2019-nir-15apr19.zip UK NIR 2019 (Issue 2) Ricardo Energy & Environment). Thanks to the DECC for clarification of what is covered by LULUCF and direction to relevant documents.

According to the Office for National Statistics, "Ideally, soils should be slowly increasing their levels of organic matter content over time as they have been doing since the last glaciation 11,000 years ago." "Soil and vegetation can sequester or emit carbon depending on how the ecosystem is managed. A high amount of carbon in the soil is a good indicator of healthy soils. Soil Organic Carbon levels are directly related to the amount of organic matter found in soils, since soil organic matter is made of organic compounds that are highly enriched in carbon. Soil organic matter (SOM) can improve the quality of soil through increased retention of water and nutrients, resulting in greater productivity of plants. SOM is also able to improve soil structure and reduce erosion, leading to improved water quality in groundwater and surface waters." "At habitat level, the most significant falls were recorded in the soil carbon stocks held in Rainfed and irrigated herbaceous cropland. The decline was due to the combined effect of a decrease in the habitat's land cover extent and a fall in its average soil carbon content (-4.5 tonnes of carbon per hectare, 1998 to 2007)" https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/uknaturalcapital/experimentalcarbonstockaccountspreliminaryestimates

Although fruit, veg, grains and some plant-based proteins and fibre are highly important components of a healthy diet, it is open to question whether a drive towards most of our food being crop-based is better for the environment, or whether we should be valuing the multiple benefits of grassland foods to a much greater extent. The carbon footprinting of foods has led to a focus on emissions in the food system, without considering what farming and production methods best manage our soils to reduce losses of carbon and promote sequestration of GHGs, whilst promoting fertility, sustainability and eco-systems services, when making our food choices. The fact that well-managed, grassland food production helps keep carbon in the soil, whereas arable production generally has much lower levels of carbon stocks is not reflected in the carbon footprint of food.

However, the IDDRI report looks at how an agroecological approach to food production, which focuses centrally on the health of the soil, in Europe can produce a nutritious diet for the projected 2050 population and simultaneously foster biodiversity; whilst, at the same time, radically reducing our land footprint for food production elsewhere in the world and somewhat reducing the land requirement within Europe too.

Other emissions related to the UK food chain not reflected in the UK GHG Emissions statistics:

The UK food chain is responsible for approximately 30% of UK emissions, when about 10% is included for energy, transport and waste management, and 10% relating to emissions from global land use change counted proportionally for the UK. (Have not looked for the most recent figures on these).

These figures also do not include all the emissions of our food chain. Almost 50% of our food is imported now and the emissions abroad, other than land use change, related to their production are not included in UK statistics. So, whereas UK GHG emissions may be reducing, the global warming potential of our consumption may be increasing, with our emissions being "offshored" to elsewhere in the world. Also, international aviation and shipping emissions are not included, although some calculations are now reported based on refuelling at UK airports and ports; however, there are problems regarding which country these should be allocated to. The extensive journey that many of our foodstuffs take to multiple countries for different stages of production, processing and packaging are not reflected even in these figures, or the land transport abroad to reach ports or airports or processing facilities, or the emissions associated with construction of hard infrastructure required.

Biogenic methane: when does methane count as a greenhouse gas?

It may come as a surprise that methane (CH_4) emissions from ruminants (cattle, sheep, goats and others), although they augment the effects of global warming, are not considered to be greenhouse gases and are part of the natural carbon cycle.

All quotes in this section from Garnett et al, FCRN in 'Grazed and Confused?' (Ref 16, p.76-8): The "ruminant-generated CO_2 that methane breaks down into is classed as biogenic, because it derives in the short-term from living organisms. As such, it is viewed as part of the short-term carbon cycle whereby animals respire the carbon that their food (plants) recently absorbed. This biogenic CO_2 is not considered to 'count' towards the total CO_2 emissions burden." Most ruminant emitted biogenic methane is in fact absorbed within ten to twelve years, and "If action is taken to reduce [biogenic, ruminant emitted] methane emissions in the absence of concerted efforts to address [non-biogenic] CO_2, then this delivers a false benefit given that an emission of [biogenic] methane is temporary and an emission of CO_2 is relatively permanent. The relative permanence of CO_2 and the cumulative effects of ongoing CO_2 release mean that we are 'committed' to warming in the future, even if all [biogenic] methane sources were eliminated today. In this sense, advocates of grazing livestock are right to warn against being distracted from tackling the deep systemic problems of fossil fuel use." So, biogenic methane, although it augments the global warming effects of greenhouse gases, unlike GHGs it does not go on accumulating in the atmosphere, and will stay at a steady state if animal numbers and method of production remain constant; in this scenario it is not causing additional warming. If animal numbers decrease there will be some mitigating effect on the true warming being created by accumulating fossil fuel emissions, however this would be on a one-off basis and would not lead to an ongoing future decline in the climate warming created by true GHGs. (See also ref 17). However, Garnett et al go on to say that the resting level of methane will be increasing as cattle numbers are increasing and the fossil fuel associated with grain production for feedstuffs associated agrochemicals, fencing and housing contribute to climate change through CO_2 emissions and also that deforestation and land degradation lead to CO_2 emissions which are GHGs (as this is stored CO_2 being released) and "of one tonne of carbon dioxide emitted today into the atmosphere, approximately 40% will persist in the atmosphere and continue to exert a warming effect for hundreds and thousands of years. Any additional emissions produced – for instance a tonne of CO_2 emitted tomorrow – will add to the warming effects of the tonne emitted today, since most of yesterday's CO_2 still remains in the atmosphere."

It is worth considering, in relationship to the last quote, that the highest use per acre of agrochemicals is in arable cultivation, (rather than on grassland) for production of grains, plant-based oils, fruit, vegetables, nuts, drinks and so on, and also for production of crops for textiles, biofuels, industrial uses and other non-food purposes. Crops are also associated with significant machinery and infrastructural needs during production, processing, storage and transport before they arrive at our table, or are put to other uses. This perhaps highlights that it is all sectors and stages along supply changes that need to focus on how products can be produced with decreased GHGs and reduced negative impacts on the environment.

We all breathe out carbon dioxide and this is also classed as biogenic, as originating in plant-based materials and part of the short-term carbon cycle. It is not included in GHGs.

Garnett et al raise the point that “Natural gas, which is methane, also breaks down into CO2 but since the source is a fossil fuel (i.e. a store of CO2 that has kept it out of the atmosphere for millions of years) it is not classed as biogenic. As such, ultimately, it is considered to add to the accumulation of CO2 in the atmosphere.”

About half of total UK methane emissions are non-agricultural and are mainly from waste management and energy supply.

Boucher et al. (2009. Ref 18) explain “For anthropogenic biogenic sources, however, the methane release comes from anaerobic decomposition of organic carbon molecules which were formed through photosynthesis in the recent past. From a carbon cycle point of view, the CO2 molecule initially removed through photosynthesis will return to the atmosphere when the carbon released as the methane molecule is eventually oxidized to CO2 in the atmosphere. It can be argued that methane emissions from ruminants, crop waste and rice paddies all come from young organic matter so that a molecule of CH4 would have removed a molecule of CO2 from the atmosphere.”

The majority of methane from ruminants is produced by the animals burping, rather than from the dung. (Defra 2017, ref 19, p.18): “Methane is produced as a by-product of enteric fermentation and from the decomposition of manure under anaerobic conditions. Enteric fermentation is a digestive process whereby feed constituents are broken down by micro-organisms into simple molecules. Both ruminant animals (e.g. cattle and sheep), and non-ruminant animals (e.g. pigs and horses) produce methane, although ruminants are the largest source per unit of feed intake. When manure is stored or treated as a liquid in a lagoon, pond or tank it tends to decompose anaerobically and produce a significant quantity of methane. When manure is handled as a solid [that is, composted on muck heaps] or when it is deposited on pastures, it tends to decompose aerobically and little or no methane is produced.”

There has been a dramatic and serious decline in dung beetles globally, due to the changes in livestock management and the use of worming preparations. These beetles and other flies and insects which feed off cow pats play an important part of the food chain for other wildlife (ref 20, 21) including bats, swallows and hedgehogs. They are also responsible for aerating the soil and assisting the absorption of the nutrients into the soil. Most livestock are wormed routinely, although there are reports that more farmers are now considering other methods of managing this problem. A member of CFBoA Sustainable Food and Drink Group, who had an organic farm, said that she never needed to use wormers on her livestock. The worms have a 3-4 week life cycle and by rotating the livestock to fresh pasture every 2 weeks these parasites never became a problem. She said that on organic farms dung is absorbed into the soil in about 10 days. On non-organic farms they can still be there 3-4 weeks later.

Methanotrophic bacteria digest methane and evolved to use methane as a carbon source. They are ubiquitous and present in soils, sediments, freshwater and marine systems with the fluxes of methane to and from land and water being very complex and still poorly understood. In soils, the activity of methanotrophs is adversely affected by compaction, disturbance and chemical applications, including fertilisers, such as nitrogen. Dung represents a significant return of organic matter to the soil and the carbon it contains provides energy for the whole system. Modern farming often doesn't utilise manures as effectively as possible, relying on fertilisers and not always returning plant matter / animal wastes to the soils appropriately. (Extracts from correspondence with Ruth Gregg, Senior Environmental Specialist - Soils and Climate Mitigation at Natural England.)

Whereas increasing ruminant numbers and certain management practices have a range of negative environmental impacts and global numbers need to be reduced, well-managed, ruminants can also have a wide range of positive impacts and benefits, which is not currently being acknowledged in the public discourse, including an important role in soil fertility and driving the vital carbon and nitrogen cycles.

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5) Beans and pulses

Protein is essential for growth and repair of the body and maintenance of good health. Although the UK is very well suited to producing first-class protein foods from grassland, the majority of the pulses (peas, beans and lentils) with the highest protein content - are not ideally suited to growing in the UK geographical range at the present time.

> 'Blueprint for UK Pulses in a post-Brexit world' (PGRO, Ref 22) says that there is a move to grow more legumes in this country, both for animal feed to reduce dependency on imported protein, such as soy, and for human consumption. A move to growing more legumes and away from the preponderance of grain production on arable soils would have many advantages for the health of the soil, including an increase nitrogen fixation, reducing the need for added nitrogen. As flowering plants, they also have benefits for biodiversity.
>
> Only the field bean or broad bean - Vicia Faba - and the vining pea (used for mushy peas, canned and snack foods) presently grow well in this country. Even these are not always fit for human consumption. "In 2017 just 10% of the marrow fat peas made the grade. These quality issues and consistency of crop performance mean there is an accented risk associated with pulse production which impacts the growers, processors and export buyers as supplies can fluctuate significantly year on year." Poor quality grain, affected by weather or pest control problems, will be used for animal feed or pet food.
>
> These problems can in part be resolved throughout the supply chain by breeding, agronomic research and knowledge transfer, if investment in resources and focus can be encouraged to deliver it. Latterly, new competition for land area has arisen with the dramatic rise in the mono cropping of maize and other species for renewable energy production, all of which have received incentives for investment.

There is now some soya and lentil variety breeding taking place enabling a start to be made on growing these in the UK, although the protein content is currently somewhat reduced. Legumes are considered to have health benefits with a wide range of nutrients and good levels of fibre, which is often lacking in diets in wealthier countries, leading to health problems.

Broad beans and garden peas are grown in the UK with the former having a much higher protein content than the latter.

The wide range of highest protein source pulses are mainly imported, such as: soya beans, lentils, navy beans (for baked beans), chickpeas, black-eyed peas; kidney beans, butter beans (Lima beans), haricots, cannellini beans, flageolet beans, pinto beans, borlotti beans and adzuki beans. The protein content varies very considerably with each of these different beans and pulses and the attributed protein content reported also varies considerably on various websites.

Climate change could make conditions in the UK more propitious for production of pulses in the future; however, linked to this is the increasing unpredictability of weather patterns. Genetic engineering is likely to be used in breeding new varieties. Whether this is desirable is debatable, however this approach to producing our food is likely to be fast-tracked after Brexit, it seems.

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6) Health recommendations on red meat and some studies into adequate nutrient intake.

It is clear from common knowledge that people can live healthily on a wide range of different dietary intakes into ripe old age. In the past, dietary intake was based to a much greater extent than now on what could be produced well in the locality or region. In the UK about 65% of the land used for agriculture is grassland and not suited to arable farming. Livestock grazing converts vegetation, that humans cannot eat, into the first-class proteins which have been a key component of UK nutritional intake through the centuries.

The NHS guidelines on red meat as part of a healthy, balanced diet says that red meats (such as beef, lamb and pork) are a good source of protein, vitamins and minerals, and some meat or meat products, or other sources of protein, are recommended as part of a balanced diet. The website gives weights and photos as a guide to portion sizes, although these may vary with gender, age and other factors. Based on data from the National Data and Nutrition Survey (NDNS 2000/01), the average total red meat consumption for men in the UK is around 88g a day. For women, it's around 52g a day. This gives an average of 70g a day for all adults, with pork products comprising the highest share. The current health advice, issued by the government, says adults who eat more than 90g (cooked weight) of red and processed meat a day should reduce their intake to 70g a day, which is the average daily consumption in the UK. [Interestingly, this is about the same amount that UK sustainable farming experts have indicated can be produced sustainably in this country.] The NHS website indicates that if you eat more than 90g of red and processed meat on a certain day, you can eat less on the following days or have meat-free days so that the average amount you eat each day is no more than 70g, or 500g a week, less for children. It says that this level of red meat intake will enable you to get enough iron in your diet providing you're eating a balanced diet that includes other good sources of iron, such as lentils, beans, eggs, fish, chicken, turkey, nuts and breakfast cereals.
(All above recommendations from the NHS website. See their website for full details. Ref 23.)

Research indicates processed and red meat may increase the risk of colorectal cancer in some people. Other risk factors include low levels of fibre in the diet, alcohol, obesity and insufficient exercise. Prof Tim Key, who co-authored a recent study and is also deputy director at the University of Oxford's cancer epidemiology unit, (2019, ref 24) said that their study would need to be seen in the context of many others and they are not suggesting that the current government recommendations need to be changed. The study found that "Compared with those in the lowest category, participants in the highest category of reported total red-meat intake were slightly older, more likely to be smokers, had a higher BMI and body-fat percentage, had a higher alcohol intake and had lower intakes of fruit, vegetables and fibre." The preponderant types of red meat consumed or how the meat was produced were not investigated. This study showed some protective effect from bread and breakfast cereals.

Some documents may refer to cooked weight of a product and some to uncooked weight, and some statistics relate to the carcass weight of meat, which can give room for confusion. It is worth also bearing in mind that the protein content of meat, dairy products, legumes and so on is much less than the total weight of the product. The British Nutrition Foundation website gives an indication of the comparative protein content per 100 grams of various meats, fish, dairy products and legumes. Legumes contain lower levels of protein than meat and dairy and also need to be combined with an appropriate cereal source for all the amino acids that we need to be present. All will contain varying levels of other nutrients and plant protein sources also contain fibre.

'Protein for Life: Review of Optimal Protein Intake, Sustainable Dietary Sources and the Effect on Appetite in Ageing Adults' (2018, Lonnie M et al. Ref 25) says that: Dietary proteins are found in animal-based foods, plant-based foods, and alternative sources such as algae, bacteria, and fungi (mycoproteins). Globally, plant-based foods are the leading source of protein, comprising 57% of daily protein intake, followed by meat (18%), dairy (10%), fish and shellfish (6%), and other animal products (9%).

They give the following data: the percentage distribution of protein intake from animal-based products in adults in the UK, in 2013/2014, aged 19–64 was as follows: 'meat and meat products' (35%), 'dairy' (14%), 'fish' (7%) and 'eggs' (4%) (from the NDNS on Protein Consumption)

In the category 'meat and meat products' the most popular foods were 'chicken and poultry' (13%), followed by processed meat (7%), 'beef and veal' (6%), 'bacon and ham' (4%), 'pork' (3%) and 'lamb' (2%).

Plant proteins were derived mostly from 'cereals and cereal products' (24%)—predominantly from the 'rice, pasta and bread' food group (18%)—followed by 'vegetables and potatoes' (8%), 'fruit' (1%), and 'nuts and seeds' (1%). The remaining 6% of protein source is difficult to classify, and comprised items such as savoury snacks, confectionary, beverages, and miscellaneous foods. There were slight differences of the daily protein intake in adults ≥65 years. The authors indicate that it may be advantageous to include more beans and pulses in our diet. However, they indicate that animal-based foods are regarded as a superior source of protein as they contain all the amino acids that we need, and are highly digestible and have high bioavailability to the body. "However, proteins do not occur in foods in isolation and the entire food matrix should to be considered when health benefits are evaluated. Apart from protein, animal-based foods provide heme-iron, cholecalciferol, docosahexaenoic acid (DHA), vitamin B12, creatine, taurine, carnosine and conjugated linoleic acid (CLA); all compounds not present in plant-based foods. Thus, moderate consumption of high-quality unprocessed animal-based foods should not be discouraged entirely."

The authors state that currently recommended protein intake for ageing adults may not be sufficient for muscle mass and strength maintenance and that “incorporation of sustainably sourced plant proteins may be a promising strategy”. “More studies are needed to evaluate the effectiveness of plant proteins in the prevention of muscle mass and strength loss.”

“Non-specific recommendations to increase plant foods can lead to unintended nutritional consequences.” according to an American study of female adolescents aged 9-18 years. “Data from the National Health and Nutrition Examination Survey (NHANES) were used to compare nutrient intakes from usual diet with those from three dietary scenarios that increased current intakes by 100 % of the following: (i) plant-based foods; (ii) protein-rich plant-based foods; and (iii) milk, cheese and yoghurt. The first two scenarios had commensurate reductions in animal products.”
Results: When currently consumed plant-based foods were increased by 100 %, there were increases in dietary fibre, added sugar, vitamin E, Fe and folate intakes. These increases were accompanied by decreases in total fat, saturated fat, Zn, vitamin D, Ca and protein intakes. Protein-rich plant foods are consumed in very low quantities in this population such that doubling their intake resulted in no real nutritional impact. When dairy products were increased by 100 % there were increases in intakes of vitamin D, Mg, Zn, Ca, K, energy, saturated fat and protein.
The researchers concluded that “Non-specific recommendations to increase plant foods can lead to unintended nutritional consequences. For adolescent girls, meeting the dietary recommendation of three daily servings of dairy improved the intake of the identified nutrients of concern while simultaneously providing adequate nutrients essential for proper growth and bone health critical during the adolescent phase.”
(2016 Demmer E et al. Ref 26)

‘Are more environmentally sustainable diets with less meat and dairy nutritionally adequate?’ - this study of Dutch adults, aged 19-69 years concluded that although a plant-based diet had a 40% lower environmental impact [concerns around the validity of current tools for assessment of environmental impacts of dietary choices are discussed above in section 2 of this document], estimated intakes of zinc, thiamine, vitamins A and B12, and probably calcium, were below recommendations. In the studied cohort, replacing instead only 30% of the meat and dairy intake had positive nutritional impacts. (2017. Seves SM et al. Ref 27).

The 2018 National Diet and Nutrition Survey (NDNS) survey published by Public Health England key findings included that:

- Iron deficiency anaemia and low iron stores were evident in 9% of 11-18 year-old girls and 5% of adult women and 1% of older women.
- Low vitamin D status was present in all age groups.
- Over the whole year, 17% of adults, 13% of older adults and 26% of 11-18 year-old children had low vitamin D status.

• Evidence of low blood folate levels (based on red blood cell folate concentrations and indicative of risk of anaemia) was seen in 28% of girls aged 11-18 years, 15% of boys aged 11-18 years and 7% of adults aged 19-64 years

Summary of Key Findings reported by the British Nutrition Foundation (2018, Ref 28).

Although any diet can be healthy if our range of food intake fulfils our individual nutritional requirement (which will vary from person to person, and during an individual's lifetime), there is evidence from a large scale study in Australia that no particular diet is a panacea: "Researchers who tracked nearly a quarter million adults aged 45 and older in New South Wales found no significant differences in all-cause mortality, meaning the likelihood of dying, of any death, between those who followed a complete, semi- (meat once a week or less) or pesco- (fish permitted) vegetarian diet, and regular meat eaters." (Ref 29)

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7) Dietary inclusions and exclusions

It is welcome that the guidelines, from the UN, the UK government, and the 2019 IDDRI report and (even) the EAT-*Lancet* report, on environmentally sustainable food choices are for a broadly inclusive and varied dietary intake and none of these guidelines advocate exclusions.

Fifty or sixty years ago most people had a dietary intake inclusive of most traditional foods: most families would share the same meal and it was not necessary for schools to provide the level of options they do now in school dinner provision. Now, it is common in the UK for people to exclude various basic food types from their diets for a range of given reasons – ethical, environmental, health and personal preference. Increasingly there have been organisational, cookery guru, media, celebrity, "expert" and corporate advocacy for a range of different diets. It is apparent that young people, as well as adults, are under cultural pressure, including from social media, fostering obsessions on weight and appearance, and powerful food chain advertising, as well as eat clean and eat green lobbyists, trying to influence what we eat. At the same time the dissociation between us as consumers and how our food is produced has never been greater. For the food chain giants, this has extended their opportunities to make a killing out of newly designed processed foods for these emerging markets, accompanied by powerful promotional messages. The media too thrive on new messages. Environmental messages on what to eat vary from one source to another and perhaps just add to the general dietary choice confusion. The once straightforward choice of what to eat or feed the family has become much more complex under the barrage of contradictory advice. No wonder we have lost confidence in what to eat "to be right" (socially, nutritionally, ethically, environmentally) and that, having made a dietary choice, then tend to make a strong emotional investment in that choice, with where we shop and what we eat becoming an important part of our self-image. This is, of course, played into by the power of advertising.

For those of us who wish to put environmental and ethical considerations at the forefront of our food and drink choices, there is a wide range of different dietary advice out there for the choosing. How do we get past that? Not it seems through relying on the carbon footprint of different diets (see point 2).

However, the IDDRI report (2019) perhaps leads us in a more interesting direction. By looking at what the land can best produce in our part of the world, whilst maintaining its fertility, ability to store carbon and provide a nutritious diet for all, whilst at the same time being compatible with improved biodiversity, and sustainable production into the future, perhaps we can move beyond the preoccupation with individual foods, or diets which advocate exclusions of traditional foods, to thinking about how all foods can be produced to higher standards, which protect the wider environment and, essentially, ensure high animal standards. Within this there is scope for those who have particular preferences or medical restrictions to choose their preferred dietary intake. **Adequate financial returns to farmers and producers to enable high environmental and ethical standards to be delivered are vital. Our buying choices are a key driver in achieving best outcomes.**

Opening up the debate

The vast majority of people globally eat a broad-based diet, which includes animal products, although particularly in parts of the world where there is the highest incidence of under-nourishment, people may not have the money or the land to allow them access to these foods (and there are obviously a range of other factors that are critical, such as harmful economic systems, conflict, impacts of climate change, problems of storage and distribution). There are many species on earth that are carnivores and many that are herbivores. Human beings have typically been omnivores and we cannot get quite all the nutrients that we need from a plant-only diet, without artificial supplements.

Vegetarianism and veganism are ideological dietary choices, with legitimate concerns about animal welfare. However, now some vegetarians and vegans, on the basis of the carbon footprinting measures, have become much more vocal in strongly promoting these dietary choices as the right environmental way forward, but are they? And could a large-scale movement away from red meat/ meat/ meat and dairy products in fact lead to negative consequences for British food production, food security and the environment? Below are some suggestions of issues to consider.

What about vegetarianism?

It is very understandable that vegetarianism has been promoted as a good choice for environmental reasons, in view of the way that dairy products are assessed by carbon footprinting tools. However, the way that the carbon footprint of foods is assessed (see point 2), leading to separation of co-products, is deeply misleading as a guide to which dietary choices are likely to be best for the environment.

Dairy cows calve, normally once a year, in order to produce milk. In the UK, dairy herd cows will, on average, calve for 4 years. The Vegetarian Society website explains that some of the bull calves are culled at birth and other calves are raised for veal or beef. The point should also be added that only one of the heifer calves will be required as a replacement in the dairy herd. At the end of their milking life dairy cows are also culled for meat. In agroecological systems, which have high animal welfare requirements, cows will often calve successfully for several more years: so, the amount of meat relative to dairy produce is then higher than in intensive dairy systems. **In a vegetarian world, where no one ate meat, all surplus calves (those not required for replacements in the dairy herd) would have to be culled at birth.** (Sometimes it can feel as if it is not "polite" to raise this fact of life in discussion with vegetarians.) However, the calves already represent a life, and considerable nutrients at birth (which will have a GHG emission cost). Reared on for meat, calves from the dairy system increase the national and global food sufficiency of essential nutrients. **The 'cut meat' from the diet message therefore <u>creates</u> ethical and environmental concerns and undermines British farming and food production.** This message, so widely promoted now, has also not had the effect of addressing the true GHGs (fossil fuel based emissions) within the system or environmental and ethical concerns, such as: preventing increasing numbers of our dairy cattle being moved into housed systems where they do not have access to grazing, or encouraging the use of home-grown proteins instead of imports, such as soy. (Most beef cattle in this country, in contrast to the US and some other countries, are mainly grass-fed; and in beef breed herds - suckler herds - the calves normally stay with the mothers until they are 6 – 8 months old. Our extensively raised beef cattle and sheep probably have the best, most natural lives of any of our livestock.)

If we were simply to leave all surplus dairy calves not needed as a replacement in the milking herd, and elderly cows, to live on indefinitely, this creates a problem of farmers being able to feed the year on year increase in the number of animals that can be understood, perhaps, by the issues now arising in India: in Uttar Pradesh the slaughter of cows has been banned by the Hindu nationalist BJP on religious grounds and, with the normal outlets for the meat no longer available, there are increasing reports of elderly unwanted cows roaming the countryside damaging crops. "Four farmers died in separate incidents across the state, while trying to protect their livelihoods from stray bulls" in just one day. The authorities are struggling to know how to cope with this issue. (30 Jan 2019. Independent. Ref 30)

One might expect, therefore, that choosing high welfare dairy and meat products (such as RSPCA Assured, organic, biodynamic or from a trusted local source) might be seen, by those who are very aware and have a particular concern about animal welfare, avoiding waste and reducing environmental impacts, as the way to help our farming systems to transition to the highest possible standards.

Yeo Valley Organics website explains how on their farm every calf is valued. Go to FAQ on their website, then 'Our Cows' and 'Health and Wellbeing' (Ref 31).

We should all be concerned about high animal welfare standards for milking and beef cattle and all our livestock and poultry. Farmers and producers can only implement the highest welfare systems if consumers are willing to pay for their produce, rather than choosing the cheapest product available. The power of the purse can be transformative: in 2000, only 16% of eggs sold were free range; by 2018, this had increased to 63% of the retail market, including an estimated 1.5% organic. This has been driven by our buying choices. This transition needs to take place for all our food (animal products and plant-based food) with a recognition that food produced to high ethical and environmental standards needs to be a higher priority in household budgets.

People are free to choose (if they are fortunate enough to have the means to do so) what they wish to eat and there are no absolutes. However, those who promote vegetarianism as "the right way" for all to reduce negative environmental and ethical impacts may wish to consider the points raised above and ask whether a much more widespread adoption of vegetarianism is really tenable as a way forward in achieving their aims.

What about veganism?

Is it the right environmental way forward for all?

Promoting a vegan diet for all has various issues that should perhaps be considered (and many of these issues are relevant for us all to consider):

a. Food security risks of a plant-only diet in view of climate change threats to harvests.
b. The question arises as to what would happen to the billions of farm animals and poultry, which exist globally, in a vegan world?
c. Carbon footprinting tools do not include the carbon losses and gains from soils or reflect the fact that grasslands are better at storing carbon than cultivated land. There is widespread agreement in research documents that permanent pasture should not be ploughed up because of the serious losses of stored soil carbon that occur during cultivation.
d. Land use: Only about 35% of the farmland in the UK is suitable for crop growing, the remaining 65% is grassland. The IDDRI report (p.61) on how agroecological approach to food production can feed the

European population says that 46% of European farmland would be needed to feed the projected 2050 European population on a vegan diet, so it's unclear whether the UK could meet the dietary needs of the population from the area of farmland suitable for cultivation. It is not just our protein requirements that would need to met from arable land, but also fats are an essential macronutrient. Grassland foods can provide protein and some fats from the same land, whereas in a plant-based diet an additional, large area of arable land is necessary to produce plant-based oils/fats/spreads.

e. The limiting factor in growing all crops is nitrogen, however inorganic nitrogen fertiliser use is also associated with a range of environmental problems. (Average application rates to arable crops per hectare are three times the rate of application to grassland in the UK.) The IDDRI report indicates that, in modelling a vegan "assumption", even if 30% of the arable land is used for legumes, which fix atmospheric nitrogen into the soil, it would only be sufficient for 60% of the necessary crop production and that this highlights the contribution of livestock to nitrogen supply in agro-ecosystems. Also, bear in mind that in the UK climate legumes may not be fit for human consumption each year.

   According to Defra: Inputs of manufactured or livestock derived nitrogen fertilisers are critical to maintain yields of food and fodder crop. Organic manures are valuable sources of the major plant nutrients, including nitrogen, and their use can lead to a reduction in applications of manufactured fertiliser. Reduced manufactured nitrogen rates on fields also receiving manure is evident across [most] major tillage crops. Cattle manure is the predominant source of organic nitrogen across farms in Great Britain although the percentage of farms using cattle [farmyard manure] has declined by 8% since 2006. (Defra. Ref 18)

f. Phosphate (P) and potassium (K) are essential nutrients for plant growth. Livestock manures are an important source.

g. Livestock urine and dung help to drive the vital nitrogen and carbon cycles.

h. Although some vegans, like others, are very focused on sourcing sustainably-produced food, this is not generalised across all vegans. The Vegan Society website focuses on avoiding harm to animals as the key issue. It is not primarily an environmental organisation and has no focus on the environmental impacts of how the food that constitutes a vegan diet is produced. The travel, shopping etc pages of the website also have no carbon cutting focus.

i. "Ensure that most of your meals contain good sources of protein, such as beans, lentils, chickpeas, tofu, soya alternatives to milk and yoghurt, or peanuts." (Vegan Society. Ref 32). For many of the main plant-based protein sources cited the UK is outside their natural geographical growing range.

   World-wide production of plant-based foods, including legumes, grains, oils, fruit, veg and nuts, is currently significantly based on agro-chemicals, industrial farming, monocultures and global trade, all of which contribute to CO2 emissions and multiple other environmental harms.

   At present 50% of our food is imported and it is noticeable that vegan recipes frequently include a very high proportion of ingredients that cannot be produced in the UK.

j. The WWF report 'How low can we go?' (2009) states that "A switch from beef and milk to highly refined livestock product analogues such as tofu and Quorn could actually increase the quantity of arable land needed to supply the UK. In contrast, a broad-based switch to plant-based products through simply increasing the intake of cereals and vegetables is more sustainable…. However, a contraction in the livestock sector may result in its collapse, the emissions relating to the UK food chain would then depend on development elsewhere. This could increase an expansion in low cost exporting countries and even add to forces driving land use change."

k. Dependence on imports and the land of others:

Even without land use abroad for animal feed (which the IDDRI report recommends should be discontinued), it is very difficult to be sure of the impacts in other countries of production of the food and drink that we import. (Ref 33).

We are already importing most of our fruit and veg and plant-based fats/oils; if we also outsource most of our protein food production, we will be ever more seriously dependent on the land of others and not contributing to global food sufficiency, in spite of having very fertile land.

According to Defra if more of our food production moves abroad this would not necessarily reduce overall global GHG intensity and could put pressure on sensitive landscapes or habitats overseas. (Ref 34).

l. At present, most transport fuel is fossil fuel-derived, with associated carbon dioxide emissions.

There is a drive for more plant-based biofuels to be used for transport fuel. Does it make sense, however, to use our grasslands and arable land to produce biofuels in order to import key nutrients, rather than eating the food types that can be produced by British farmers directly from that same land? The question of land being used to produce crops to feed animals, rather than directly for human consumption,(feed vs food) is often raised; it is therefore also reasonable to raise the issue of land use for fuel crops to import the food, rather than using the same land to produce food for local consumption (fuel vs food).

Bear in mind that "UK biofuel use in the first year of monitoring [in 2009] required around 3.46 million hectares of farmland, most of it overseas. That's the size of Northern Ireland, just to provide 3% of our transport fuel." ('Biofuel crops: food security must come first' 29 Aug 2013, *The Guardian).*

m. Many imported crop foods, including some grains, nuts, citrus fruit and vegetables will have been irrigated, and water scarcity is now becoming a major threat in many areas of the world.

"A vast majority of the world's population lives in countries sourcing nearly all their staple crop imports from partners who deplete groundwater to produce these crops, highlighting risks for global food and water security… Excessive abstraction of groundwater for irrigation is leading to rapid depletion of aquifers in key food-producing regions around the world (such as north-western India, the North China Plain, the central USA and California…. This depletion of the largest liquid freshwater stock on Earth threatens the sustainability of food production, and water and food security, not only locally but also globally via international food trade." (2017. Carole Dalin et al, Nature, Ref 35) ('Towards a water and food secure future: Critical perspectives' FAO, Ref 36)

Drought, particularly in soils with low levels of organic matter, contributes to loss of carbon from soils, top soil erosion and reduction of eco-services. There are benefits and drawbacks to irrigation. Only 1% of extracted water in the UK is used for agriculture, mainly in the arable south-east.

Rice uses 40% of all irrigation water globally. Rice production for the export market is now having major effects on water sufficiency in some producer countries. Rice is also one of the largest human-induced sources of methane.

n. According to the UN one-third of global soils have been damaged by industrial farming. This has an impact on the soil food matrix and wildlife too. Many of the problems can be improved by mixed farming and regenerative management approaches, especially regenerative grazing, and discontinuing or minimising the use of agrochemicals. No-till arable management can be very successful, although it has certain challenges in this country. It is widely reliant at present on the use of glyphophosphate to kill off the cover crop prior to direct sowing.
o. There is a natural synergy and symbiosis between crops and animal production for: fertilisation of soils; use of crop wastes; varied and scenic mosaic landscapes; and opportunities for wildlife. (ref 37)
p. Many of the crops that vegans eat, including many of the hydroponically produced fruits and veg, will have been fertilised with animal or poultry manures.
q. Is an inorganic medium for growing food really what vegans want? The cycle of life and death are at the centre of earth's vitality and the health of the planet, from microorganisms to all living creatures and throughout the food chain.

What about pescetarianism?

'The dilemma of healthy eating and environmental sustainability: the case of fish' (2012, Clonan A. et al, University of Nottingham, Ref 38) Extract: "Objectives: Despite widespread concern over exploitation of the European Union's fish stocks, dietary guidelines in the UK continue to recommend two portions of fish per week. The present study sought to investigate whether health and/or sustainability are motivating factors when purchasing and consuming fish and whether there are sociodemographic trends.

Conclusions: The number of consumers purchasing fish for health reasons was more than those seeking sustainably sourced fish; yet, they still failed to meet the recommended intake set by the Food Standards Agency. Dietary advice to the public to increase consumption of fish conflicts with the prevailing pressure on fish stocks. Clear advice should be communicated enabling consumers to meet nutritional needs while protecting fish stocks."

Have the important recommendations for these guidelines been responded to?

- **The beef question**

Globally the number of cattle has been increasing and this is problematical in a range of ways: what they eat; land use; methane; water use. However, the simplistic "cut meat" message, so widely promoted, has done nothing to stop the trend towards mega-dairies, intensive pig and poultry production, and now, some movement of our traditionally grass-fed beef cattle, into large finishing units. There are many advantages to moderate levels of livestock in a sustainable food and farming system which are not being discussed at present. And it should be remembered that dairy cattle are cattle too!

Issues often raised:

- **Fed on grain which humans could eat – destroying the rainforests – and using a lot of water:**
  The debate about meat, and particularly beef, in this country has been greatly influenced by films such as Cowspiracy and use of global or US data, rather than looking at the picture in the UK.
  Most beef cattle in this country are raised on naturally rain-fed grassland through the summer months. To avoid damage to pastureland and soil structure most will be housed through the winter months and mainly fed on grass products. In the UK the majority of the grain and concentrates (including soya) is fed to poultry and pigs and our dairy cattle consume more than our beef cattle.
  Only 1% of the water extraction in the UK is used for agriculture, much of it in the south east. This is the area of the country with the most intensive arable cultivation.
  The IDDRI study indicates that all livestock in Europe could be extensively produced on traditional grasslands in an agroecological system, with some home-produced protein and cessation of imported soy.
  In response to the EAT-*Lancet* report, researcher Anne Mottet, a UN FAO livestock development officer specializing in natural resource use efficiency and climate change, spoke out in Jan 2019 about "incorrect, if widespread, information and understanding about the so-called 'food-feed competition'." The study by the FAO published in *Global Food Security* in Dec 2018 "found that livestock rely primarily on forages, crop residues and by-products that are not edible to humans and that certain production systems contribute directly to global food security, as they produce more highly valuable nutrients for humans, such as proteins, than they consume. This study determines that 86% of livestock feed is not suitable for human consumption." (Refs 39, 40).
  UK farmers describe how they are producing livestock on grass, without extra concentrate feeds, on the Pasture for Life website: 'It can be done - The farm business case for feeding ruminants just on pasture'. This includes a description by Tim May, the Hampshire farmer who gave a talk to CFBoA in 2014, describing why he converted the family farm to mixed farming after crops started failing and finding that soil conditions were deteriorating in their arable-only system. (Ref 41).
- **Too much land:** Globally this is a huge issue with rain forests being seriously eroded both for grazing and for producing soya, palm oil and other grains. Savannas are also being ploughed up for arable land to produce animal feedstuffs. There are other contenders also leading to enlargement of land use, some of which is also in regions with sensitive eco-systems and may displace local people and wildlife: crops for human consumption, including vegetable production; products with low or no nutritional value, such as drinks and sugar; timber products; crops for biofuel feedstocks; crops for textiles; rubber production; crops for industrial and medical uses; mining; human settlement; and production of the third of the global food supply that is wasted (accounting for nearly 3.46 billion acres of land - around 30% of the world's agricultural land area.)
  Meanwhile, in Europe our land use has decreased, due to more intensive production, retraction from traditional grazing lands and sourcing cheaper or more exotic foods and other products from elsewhere in the world. To reduce our negative impacts, we need to step more lightly on many fronts.
- **Methane:** (See section 4 on Emissions with subsection on Biogenic Methane)

➢ **Health:** (See section 6 on NHS guidelines on red meat as part of a healthy, balanced diet.)

➢ **Grazing damages the environment - displacing wildlife: grasslands should be used for alternative uses: eg planted with woodland; nature reserves; production of biofuels:**
Some increased planting of woodland is desirable. However, much extra tree biomass and carbon sequestration can be achieved advantageously through agroforestry and there is increasing evidence of wood pasture being better for wildlife than closed canopy woodland. Many researchers and conservation organisations regard managed livestock grazing as a critical component in restoring biodiversity. It is the management systems rather than the animals that have been responsible for the declines in biodiversity and it is possible to change that with benefits for all. The largest declines in wildlife in the UK are in the south-east where there are the lowest levels of grassland and livestock farming.

- **What about lab meat?**

‘Cultured lab meat may make climate change worse’ (19 Feb 2019. BBC News. Ref 42):
Essentially, the process involves collecting stem cells from animal tissue and then getting them to differentiate into fibres, these are then developed and grown into a sufficient mass of muscle tissue that can be harvested and sold as meat.
Researchers from the Oxford Martin School looked at the long-term climate implications of cultured meat versus meat from cattle.
"The climate impacts of cultured meat production will depend on what level of sustainable energy generation can be achieved, as well as the efficiency of future culture processes," said lead author Dr John Lynch.
"If the lab-grown meat is quite energy intensive to produce then they could end up being worse for the climate than cows are."
“Artificial meat may result in the presence of organic or chemical molecule residues in water, because the process would need to produce huge amounts of chemical and organic molecules, such as hormones, growth factors, to add to the culture medium to grow the meat” said Prof Jean-Francois Hocquette, at the French National Institute for Agricultural Research, who wasn't involved with the study.

See also: ‘Cultured meat: state of the art and future’ [It doesn’t sound very enticing, better not to know how it is made!] FCRN (Ref 43).

The development of lab meat involves genetic modification processes, although alternative terminology is often used.

Meat contains a range of varying nutrients depending on the sort of animal, the breed, which cut of meat is used and the way the animal has been produced. This range of complexity may not be replicated by lab meat. Food scientists and highly processed foods now dominate our food chain and eating habits. Can we trust them to produce what is best for our health? The advice from the UN on healthy and environmentally sustainable eating is to eat very little highly processed food, high in fat, salt and sugar and other additives, which are necessary for flavour because of the damage to the natural nutrients during processing. This level of processing can also damage the food structure and can lead to nanoparticles in the food. Does lab meat offer better reassurances? It would also further undermine farmers' livelihoods, redirecting all income to the biotech industries and manufacturing corporations, with a further redirection of money away from the countryside and rural communities. What would happen to the dairy beef, which is a co-product of our milk and cheese production, and constitutes around 50% of UK beef?

A large scale move away from animal to plant foods and lab produced foods raises important questions concerning the future fertility of our soils for producing crops, the ability to avoid further damage to their carbon-holding capacity and their capacity to retain nutrients, moisture and mitigate drought and flooding. The UK Greenhouse Gas Inventory Annexes, 1990 to 2017 (submitted in 2019), P. 734, section on 'Change in soil carbon stock due to cropland management activities' highlights the importance of not just returning crop residues to arable land, which will achieve low to medium organic matter returns to the soil depending on the crop type, but that the addition of manure to the land moves the vital organic matter returns to the soil up to the next category. Bearing in mind that croplands are already significantly depleted in soil carbon compared to permanent pasture, a further move towards specialist crop farming and away from the benefits of grassland and mixed farming, where there is a synergy between animal and crop husbandry, does not bode well.

On the back of current interest in vegetarianism and veganism, many vested interests have seen big opportunities for super-sized profits, so they are now swinging their corporative advertising might against meat and behind plant-based foods. This includes supermarkets who are strongly promoting new ranges of processed food products made from relatively cheap plant sources at a high mark-up price; to bioenergy producers who wish to use farmland crops and grassland for bioenergy; to scientists eager to use GM technology for transfer to commercial development of highly profitable end-products; to government keen for the revenues and export opportunities. There is thus a cross-over between the cashing in on the plant-based food narrative and the GM industry. "Suddenly, fast-food chains and discount superstores – the very market-makers that helped induce agriculture to become ever bigger, faster and more reliant on industrial chemicals and genetic modification – are processing ultra-processed meat substitutes with names such as 'Beyond Meat' and the 'Impossible Burger', produced by companies headquartered in Los Angeles and Silicon Valley that are staffed by former tech workers." Venture capital firms and corporate giants, such as Nestle are ploughing in millions and "the Swiss giant recently predicted its vegan business – including a forthcoming meatless 'Incredible Burger' – would be worth billions in the next decade." (FT.com/magazine June 15/16 2019). Many of the plant foods used in these products will have come from industrial monoculture agriculture with widespread use of agrichemicals, from global markets; some of the crops will have been genetically modified.

It is far from clear whether either human health or the long-term interests of the environment are best served by this utopian (for which read short-term, profit-driven) science.

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8) Grassland versus cropland foods: food security

Perhaps the most compelling case for maintaining diversity of food production and consumption, with grassland-produced animal foods as well as plant-based foods, comes from the evidence and warnings of increasing crop failures due to extreme weather conditions.

Food security is an increasing concern for the future, due to the impacts of climate change on food production. It is thus perhaps a matter of concern that the EAT-*Lancet* report recommends a transition to a planetary health diet of mainly plant foods with very low levels of meat consumption. Its recommendations include higher consumption of pork and chicken relative to dairy, beef and lamb. However, pigs and poultry globally are mainly intensively produced and in the UK are fed more grain and concentrates (including soy) than our dairy and beef cattle herds combined. A dairy cow on average is fed about five times more concentrates than the average for animals raised for beef. So: grain-dependent pig, poultry and dairy production are currently most at risk from global crop failures, although this may be mitigated in part by their ability to thrive on damaged crops and crop wastes, depending at what stage in growth the crop damage occurs and how much can be salvaged. The separation of crop production and livestock rearing in modern specialised farming systems and the outsourcing nowadays to other countries of some of our animal feed is likely to make this more difficult than in mixed farming enterprises. Many cattle and sheep are raised on grass products alone which would be likely to improve food security.

A ‘New article from the US warns caution over the blind assumption that we can 'tech' our way out of climate change’: “We've got tools. We can modify crops. There are options," said Alyssa Charney, a senior policy specialist at the National Sustainable Agriculture Coalition. "But, at the end of the day, the pressures we're expecting, and are already happening, are greater than the tools we have."(4th Jan 2019. Ref 44)

The following warnings (see extracts below) from the Met Office and the UN Food and Agriculture Organisation were reported in an article in the Guardian on 15 July 2017 (Ref 45) entitled ‘Maize, rice, wheat: alarm at rising climate risk to vital crops’:

- Simultaneous harvest failures in key regions would bring global famine, says the Met Office.
- Governments may be seriously underestimating the risks of crop disasters occurring in major farming regions around the world, a study by British researchers has found. The newly published research, by Met Office scientists, used advanced climate modelling to show that extreme weather events could devastate food production if they occurred in several key areas at the same time. Such an outcome could trigger widespread famine. The scientists, led by Chris Kent, of the Met Office, focused their initial efforts on how extreme weather would affect maize, one of the world’s most widely grown crops. Heat and drought were the prime risks, although flooding was also included in the analysis.
- The group found there is a 6% chance every decade that a simultaneous failure in maize production could occur in China and the US – the world’s main growers – which would result in widespread misery, particularly in Africa and south Asia, where maize is consumed directly as food.

- An example of the kind of disaster that could occur is provided by the maize harvests that failed last year in Africa. Communities in Zambia, Congo, Zimbabwe, Mozambique and Madagascar were affected and six million people were left on the brink of starvation. A joint failure of China and America's maize harvest would have a far greater impact. According to the UN Food and Agriculture Organisation, maize, rice and wheat together make up 51% of the world's calorie intake. Billions of people rely on these crops for survival. Any disruption to their production would have calamitous consequences.
- In addition, there may be risks of similar events affecting rice, wheat or soya harvests.
- "We have found that we are not as resilient as we thought when it comes to crop growing", said Kirsty Lewis, science manager for the Met Office's climate security team.

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9) What about carbon storage in the soil and the health and fertility of the soil?

Generally, trees, bushes and grasslands are better at laying-down of carbon into the soil than cultivated land. Disturbance of the soil by cultivation tends to release stored carbon back into the atmosphere. The vitally important but very complex role of the soil in carbon sequestration (long-term storage), and how this is affected by the way our food is produced, is not accounted for in most carbon footprinting tools for individual foods or diets; and yet soils should be acting as a huge carbon sink.

Concern about the state of soils has been building over many years and in 2014 researchers at Sheffield University warned that there were only 100 harvests left in UK farm soils. The same warnings came in 2015 from the UN, who said that a third of global agricultural soils have been damaged by modern industrial farming. Intensive farming techniques with heavy use of fertilisers, herbicides, fungicides and pesticides are believed to be major factors in these problems; increasingly heavy machinery has caused compaction of soils and a move away from mixed farming, to a separation of crop and livestock production in specialised farming systems has contributed to the reduced returns of organic matter to arable soils. The south-east of England where specialist arable farming predominates is the most severely affected area in the UK, with low soil organic matter content and problems with drought and soil erosion.

Although this intensive, specialised approach to food production has enabled us to have cheap food, it has led to loss of carbon, loss of soil structure and nutrient retention, erosion of topsoils, loss of biodiversity and other serious environmental harm. The British Trust for Ornithology (BTO) says that the arable south-east of England shows the UK's greatest decline of farmland birds driven by losses of more than 50% in farmland specialist species: “Compared to other regions, south-east England has experienced the greatest degree of long-term agricultural intensification, fragmentation of natural habitats and urban expansion.” (ref 46).

A study in Germany also raised the alarm reporting that the number of flying insects has declined by up to three-quarters.

A report by the Committee on Climate Change, said the UK has lost 84 per cent of its fertile topsoil since 1850, with the erosion continuing at a rate of 1cm to 3cm a year. Environment Secretary, Michael Gove, said in October 2017, that parts of Britain’s farmland are just 30 to 40 years away from becoming barren wastelands with 'eradication of soil fertility'. He said that ‘We have encouraged a type of farming which has damaged the earth”: farmers needed to be incentivised to tackle the loss of soil fertility and the decline in bio-diversity more generally. (Refs 47, 48). However, it is not clear that there will be direct incentivisation for improving soil health.

Nevertheless, the Government focus on soil health, the consultations relating to the Agriculture Bill and the Environment Bill and the realisation among farmers that crop yields have declined in recent years, in some areas, has led to a significantly increased positive focus amongst farmers and in the farming press on the soil health and regenerative agriculture. After decades of being advised by the agri-science sector to manage farmland through chemical inputs, with much of the farming industry being on an intensive and expensive agri-chemical treadmill, there is now clear excitement and relief being expressed by some farmers who are finding that (even if the farming remains very high tech) regenerative agricultural techniques can improve soil health and productivity. These techniques may include introducing legumes into rotations to increase nitrogen fixation; more diverse rotations; rotations to suit each field; use of mixed species leys (grassland) with deep-rooting herbs; rotational grazing; the return to the soil of more organic matter, such as chopped straw, manure or other bulky organic matter; use of cover crops; and direct drilling to preserve and improve soil structure. Soil Farmer of the Year 2018, Essex farmer, Simon Cowell, has combined home-made compost with an extremely diverse rotation and minimal soil disturbance. He has built his system around supporting mycorrhizal fungi in the soil which have a symbiotic relationship with plant roots and help them absorb nutrients. This has resulted in healthier, more resilient crops (Ref 49). For some farmers these approaches are bringing down costs in machinery, labour and through reduced use of “fertilisers and chemicals, which in turn leads to a huge increase in insects, birds and wildlife, as well as fewer floods and more resilient crops during droughts” and enabling the soil to absorb more greenhouse gases (Ref 50).

However, all is not straightforward! Unlike the US where winter weather is colder, in the UK green manure crops used in arable systems do not die off in winter, therefore these crops are usually terminated with glyphophosphate to allow direct (no-till) drilling of crop seeds, which is not allowed in organic farming. Roller crimpers are being trialled in this country on green manure crops with the aim of avoiding the need for herbicides, although these also present some challenges in our climate (Ref 51). Also, the ability to reverse the carbon losses from arable land with the no-till systems do not seem to be guaranteed and, in some cases, it can lead to increased emissions of nitrous oxide. (Ref 52).

Happily and unhappily, according to Defra "In comparison to many EU soils (particularly those of southern Europe), the UK tends to have fairly high soil carbon concentrations and whilst there are uncertainties surrounding the data on trends of soil carbon in the UK (with countryside survey data indicating no significant changes whilst the National Soils Inventory indicates losses of soil carbon) there is little evidence to support the conclusion that soil carbon sequestration can significantly offset UK emissions. There is some evidence to suggest that UK arable soils may be losing soil carbon, both through the National Soils Inventory data and in observational studies. Other evidence suggests that arable soils may now be reaching or are at a new lower equilibrium level following previous losses due to drainage and historic land use change. There may be some scope to identify management practices to increase soil carbon concentrations in arable systems under UK conditions, or at least reduce further losses. In many parts of the world, minimal or zero tillage systems seem to result in increases in soil carbon concentrations, at least at the soil surface. Research on minimum tillage in the UK (and other parts of the world) indicates a redistribution of soil carbon with depth rather than large absolute increases in soil carbon sequestration. Unfortunately, for the soil types predominant in the UK, compaction may be an issue under reduced tillage systems with consequent increases in nitrous oxide emissions. Given the relative strength of nitrous oxide as a greenhouse gas these enhanced emissions are likely to exceed any benefit of soil carbon sequestration." (2017, Defra, Ref 53, p.18) (See also ref 53).

The Soil Association document 'To plough or not to plough' says that "Despite the use of ploughing on most organic farms, organically-farmed soils have been found to have on average 21% higher levels of soil organic matter than non-organic soils." "As several studies have reported, the better performance of organic farming in sequestering soil carbon may be because organic systems have between 32% and 84% greater microbial biomass; and organic farming systems appear to have positive effects on soil microbial community size and activity. A long-term study published in 2007 concluded that 'organic farming can build up soil organic matter better than conventional no-till farming can'. A recent U.S. study found that organically managed soils store more carbon for longer periods and have on average 44% higher levels of humic acid—the component of soil that sequesters carbon over the long term—than soils not managed organically." "The immediate need is to restore agricultural land to as close to its original soil carbon level as we can; as well as offsetting a significant portion of our GHG emissions, this will improve crop yields, increase farmland wildlife and, by improving the water holding capacity of soils, will reduce flooding and farming's vulnerability to droughts." (2018, Ref 54).

A report prepared for Defra (2014) says: "Increasing manure inputs to Cropland would be the most effective way of increasing SOC [Soil Organic Carbon] stocks under tillage land. However, the scope to do this is constrained by the availability of manure. Other organic wastes could be used to supplement farmyard manure, but their use is regulated to avoid soil contamination. Increasing inputs of nitrogen fertiliser would be unlikely to have a net benefit on greenhouse gas emissions if nitrous oxide emissions are considered. Changing the tillage regime only gives limited benefit, and the scope to reduce tillage on UK Cropland appears to be small." (Ref

55, p.64). There are both potential benefits and risks in the application of digestates from anaerobic digesters to farmland (Ref 56) and from biosolids (treated sewage sludge). "Organic manures are valuable sources of the major plant nutrients, including nitrogen, and their use can lead to a reduction in applications of manufactured fertiliser." (2017, Ref 52, p.72). 'Tips on how to get [arable] your soils back in to better shape' in the (Farmers Weekly 22 Sept, 2017, Ref 57) looks at the pros and cons of different sources of organic matter with four measures of soil health and crop yields and concludes that farmyard manure is the preferred source in most situations. Cover crops are considered to be useful in various respects, but a very slow way to increase soil organic matter. One of the measures recommended for assessing soil health is counting the worms "in November and spring when soils are slightly wet and they are near the surface. Count the middens, which are the piles of organic debris (twigs, leaves, straw and stones) gathered by anecic earthworms. Typical values seen are 0-3/sq m for plough-based systems, 3-15/sq m for min till and 15-60/sq m for zero-till."

The clear message, including in UN and government documents, is that permanent pasture should definitely not be converted to arable production, as this results in a rapid loss of the deep stores of sequestered soil carbon. Well-managed grasslands are widely reported to have a high soil carbon content. Loss of carbon and damage to soils from both over-grazing and under-grazing are a matter of concern and widely documented globally, nevertheless it is worth noting that carbon stocks tend to diminish in abandoned pasture. Soil carbon and the natural fluxes of carbon in and out of the soil are very complex and far from fully understood. Soil organic carbon content can vary with, for example, climatic zones, season, temperature, rainfall, soil type and land management and it is well-documented that grazing intensity, grass species and animal type can all make a significant difference. Carbon can be stored in different ways with relatively unstable storage in superficial soil levels and relatively stable sequestration at deeper levels (importantly this too can be lost when the soil is disturbed by converting grassland to arable land). It has become clear to researchers over recent years that carbon can be stored much deeper in grasslands than previously realised.

Certain grazing practices can restore organic matter, fertility and soil organic carbon to grasslands, and also to degraded arable soils much more quickly than green manure crops and no-till arable management. Some studies show that regenerative (rotational) grazing can lead to four times more additional soil carbon per hectare a year being stored compared to the regenerative impacts of no-till methods of horticulture. Machmuller MB et al (2015) found in an extensive region of severe soil degradation in the southeastern USA "within a decade of management-intensive grazing practices soil C levels returned to those of native forest soils" (Ref 58). (See also ref 59).

Rotational grazing, which involves moving animals on to fresh grazing frequently, is supported as having the best outcomes for soil health in 'A Global Meta-Analysis of Grazing Impacts on Soil Health Indicators' by Byrnes, R. C. et al (2018). Amongst the references in the document, the following highlight the important role of grazing: "Global grazing lands occupy up to one-half of the earth's terrestrial surface, ?3.4 billion ha (FAO, IFAD, and WFP, 2015), supporting the livelihood benefits and subsistence of millions of people (Glenn et al., 1993; LeCain et al., 2002; Sayre, 2007; Derner et al., 2017). These lands are often marginally productive compared with more intensive agricultural landscapes, occupying land otherwise not historically suitable for agronomic cultivation. However, the pressures of a growing global population are increasingly exposing grazing lands to risks of conversion to other land uses such as higher value, intensively managed crops or urban development (Cameron et al., 2014). This is of concern, because grazing lands support high levels of biodiversity (Fuhlendorf and Engle, 2001; Fabricius et al., 2003; Havstad et al., 2007). Grazing lands also supply a multitude of ecosystem services including regulation and storage of water flows (Schlesinger et al., 2000; Havstad et al., 2007), nutrient cycling, and C sequestration (Schuman et al., 1999; Conant and Paustian, 2002; Morgan et al., 2016). Globally, grazing lands play a major role in climate change due to massive stores and fluxes of C, storing >10% of total biomass C, up to 30% of the total soil organic C (SOC), and 0.5 Pg C yr−1 (Scurlock and Hall, 1998). Recent estimates suggest that improved grassland management could generate increases up to 0.28 Mg C yr−1 (Conant et al., 2017)…… Evidence suggests that some grazing management strategies can positively benefit ecosystems and could even reverse negative impacts of poorly managed grasslands through enhancement of N cycling, primary production, and flow and sequestration of C (Turner et al., 1993; Soussana and Lemaire, 2014). Conant and Paustian (2002) concluded that up to 45 Tg C yr−1 could be sequestered globally on restored grasslands, if grazing intensities were reduced from heavy to moderate levels." (2018, Byrnes, R.C. at al, Ref 60).

According to the UN the "FAO estimates that an annual carbon sequestration potential of 409 million tonnes CO2 -eq is possible in just over one billion ha of the world's grassland area. In 46 percent of this area, this can be achieved by increasing both grazing pressure and grass consumption. And in a further 31 percent of this area, reducing grazing pressure was shown to increase grass production and consumption. In addition to mitigating CO2 emissions, these practices increase soil health and grass production and provide environmental co-benefits (e.g. biodiversity and water quality), particularly where the restoration of degraded grasslands is involved." (2013, Ref 61, p.89).

"Non-permanence risks" are raised as key issues in this UN document and widely elsewhere. This includes concern that any gain in the carbon stocks in the soils of permanent pasture may be reversed by changes to unsustainable grazing practices or other changes in land management, leading to release of global warming emissions, or, for example, carbon emissions from the soil in severe drought. According to Defra: "Longer term studies measuring soil carbon concentrations over multi-decadal time periods seem to indicate that after any change in management, soil carbon will change to reach a new equilibrium concentration. This means that soils cannot indefinitely continue to store carbon, but rather tend to accumulate carbon rapidly at first before stabilising in the long term. Such changes occur over the order of 20 to 100 years, and are rapidly reversed if management reverts to the original practice. This is particularly true of grassland to arable conversions, so grass leys in crop rotations appear to have limited potential to sequester carbon on a permanent basis." (Defra, Ref 52). There seems to be limited interest in Defra documents in advocating an increase in the now low levels of organic matter in UK arable soils for this reason. The question could be posed that if mixed farming is widespread in a region and encouraged, then surely the return to arable cultivation of some temporary grass will be balanced out by other land going back under grass, thereby beneficially always keeping some carbon out of the atmosphere? Becky Willson (Duchy College) says that: Grassland is essentially a regenerative crop in terms of soil health, it will improve soil structure, feed soil biology and is all round a good thing in terms of soil carbon levels and research into shallow cultivation, without turning the soil over, is now showing that less carbon is lost than with deeper ploughing. Also, the benefits of having grassland (or by mocking the grassland system by planting cover crops or intercropping (planting an understorey) within an arable system) are wider than just carbon.

CFBoA member Cate Mack says: “From my own organic farming experience, where we used a ten-year rotation for two thirds of Norwood’s 340 acres, I can reinforce the fact that very shallow ploughing, plus the use of cover crops and clover, makes a huge difference. For example, we would grow cereals (oats, winter or spring wheat) undersown with grass and clover, and when the harvest was over, we put sheep in to graze down and start to fertilise the soil. Incidentally sheep are brilliant at getting rid of black grass – one of the invasive grasses that farmers have been told can only be removed through use of chemicals!”

Another UN and government key area of concern is that carbon saturation may be reached in well-managed permanent grassland, or, over time, in grassland under regenerative management, where no more carbon can be accumulated and carbon flow in and out of the soil is in equilibrium. The implications are that some of the emissions from grazing animals will then be added to the atmosphere (on a long-term basis).

However, does this make sense? If the animals are only eating vegetation, surely there is indeed a state of equilibrium where the carbon removed through grazing is also returning (over time) to the soil ultimately to maintain that state of equilibrium. Also, potentially, could the increasing soil depth through returns of the dung and increased activity of soil biota, go on indefinitely increasing the volume of soil available to store carbon? In regenerative grassland management, is the kick-starting of the carbon cycle and nitrogen cycle by the grazing, urine and dung creating enough renewed organic activity in the soil to capture over and above the emissions of the grazing animals; thereby capturing the emissions (over time) from the animals, but additionally other atmospheric carbon? In response to these questions Becky Willson from Duchy College replies in correspondence: “This all depends about how you report the carbon. If you are reporting carbon as a percentage (like you would soil organic matter percentage) then yes you will reach an optimum over which you are effectively farming peat. However, if you change the way that you look at the carbon and report it as a yield rather than a percentage (in tonnes per hectare) then in theory the possibilities are endless! There is a firm school of thought that once you have ‘saturated’ the shallower soil profile then you start building new soil. Whether we have lots of that capacity here in the UK remains to be seen – but some of the research which is being done is looking at the carbon sequestration over different soil depths to see whether in those systems who have been working on this for a while they start to turn some of the more active cycling carbon (found in the top layers of the soil) into the more stable humus.

“Humus has a longer residence in the soil than plant debris” (2012, Ontl, T.A., Ref 62). With lack of humus in soils and serious losses of topsoil around the world, the earth is losing its blanket of living, breathing insulation as well as carbon, nutrients and wider eco-system services, including the soil food web, which is the base of the food chain for so much of our wildlife.

Living soils, rich in organic matter, are essential for soil health and the sequestration of carbon into more stable forms, and soil microbes, including bacteria and fungi, and myriad other creatures in the soil such as worms and beetles, are central to the processes involved. This busy activity in healthy soils is also vital for the production of food replete in nutrients. The UN during International Year of Soils 2015 raised a major concern about the emergence of "hidden hunger": malnutrition due to the decreasing levels of micro-nutrients (vitamins and minerals) in foods. A remarkable drop in nutrient levels in foods between 1940 and 1991 is recorded in UK Medical Research Council documents. The mineral content in vegetables over that time, on average, contained 24% less magnesium, 46% less calcium and 76% less copper.

In a 'Critical review of the impacts of grazing intensity on soil organic carbon storage and other soil quality indicators in extensively managed grasslands', Abdalla et al (2018) report that "Generally, grazing stimulates pasture growth, so although the animals under high GI [grazing intensity] consume more C [carbon] from the system and respire it, grazing returns (urine and faeces) recycle the C so, the input to the soil remains similar." In a moist cool climatic zone "Although grazing in the warm-season is good for plant diversity conservation and nutrient storage in the topsoil, grazing in the cold season can enhance for C and N [nitrogen] storage in deep soil layers (Gao-Lin et al., 2017)." In different conditions light, moderate or high grazing intensity may have the best outcome for maintaining or enhancing soil carbon storage. (Ref 63). In this country, most cattle are housed through some of the winter months to avoid damage to pasture and compaction of soils, although on some soils/ grassland types year-round grazing can be practised.

So, well-managed grassland farming has many very important positives. Also, there is increasing literature indicating that maintaining, and converting to, traditional mixed farming systems which, as well as permanent pasture, may include temporary grassland in a rotation with arable crops, has many environmental and soil health benefits over the specialised systems which predominate now. In 'Integrated crop and livestock systems in Western Europe and South America: A review', Jean-Louis Peyraud et al (2014): "Having recapped the mechanisms behind the specialization of systems and territories, we examined the extent to which the development of innovative mixed-farming systems that reconnect livestock and crop production on various territorial scales (farm, district, region) can reduce the negative impacts of agriculture on the environment, produce valuable ecosystem services and achieve acceptable economic efficiency for farming enterprises." They give examples "to show that mixed-farming systems increase the possibilities of better recycling of nutrients within systems, limiting recourse to the purchase of increasingly expensive inputs and safeguarding the biodiversity of agricultural ecosystems." (Ref 64).

A small book, *The Natural Order,* of curious interest, of its time, was edited by H.J.Massingham in 1945 to War Economy Standards. It is a collection, for which his alternative title was 'A return to husbandry' and there was already a concern by some about the impact of agrochemicals on the land. Michael Graham writes about his dream of the perfect management of grass. He lists grasses from three classes, with many different seasons and qualities, some very palatable, some less so, that can give an endless variety of combinations suitable for different soils and conditions. Along with the grazing management he describes how "All that should be done [on these perfect pastures] is to follow the best practices in their care: scatter dung with sweeps of a fork; harrow and roll them in March; keep mixed stock, that is cattle and sheep, on them; and graze them hard enough to let the soil see the sky for a week, once in a year or two. We can be quite sure of one thing – that the key to the success of this pasture lies in the soil. If we part the grass we will always find bare soils among the stools – no moss covering it, and we will find something else, namely worm-casts." He describes how the worms and the soil need air, and the worm provides this for the soil; how the worms need organic matter and this is partly provided from grass roots, which have been eaten by beetles and wireworms. This pruning nourishes the new roots "because the earthworm keeps bringing soil up on to the surface, where it acts as a surface mulch, from which the plant foods are washed down into the top two or three inches of the soil…The mole, who lives on earthworms, does the same thing in a rather clumsier manner, which is often inconvenient. But doubtless the earthworms need thinning too...The tunnels and taps of the earthworm help the rain to get down into the soil, with its burden of nitrous acid and of dissolved air, and this is undoubtedly another service to the grass. General loosening of the soil is also necessary to help aeration and percolation, and this loosening is done by the tap roots of the clover and dandelion. As the roots grow and thicken the soil has to move, and this must be the chief compensating agent of the treading of the stock, which would otherwise pack the soil harder and harder, and thus reduce aeration, water penetration and the travels of the important earthworm. As R.H.Elliot wrote: 'The cheapest, deepest, and best tillers, drainers, and warmers of the soil are roots.' The deep roots do another service…These plants are known to be 'mineral efficient', that is their shoots contain valuable minerals, even when growing on soils that are poor in minerals. The acid formed in the breathing of their roots is evidently particularly potent in liberating the vast store of mineral, lime, and phosphate, that there is in every soil – enough to grow a hundred crops in the poorest. In this way the minerals can reach the stock, and, through their dung, can nourish the rye-grass and meadow grass, whose roots have not this power….". Here we have an acute observer, even if scientists today may perhaps wish to refine on some of the detail.

Red clover was known earlier in the last century, to be essential grazing for the strength that shire horses needed to provide the 'horse power' to work the land. Complicatedly, but interestingly, red clover is now known to suppress certain chemicals, which leads to fewer amino acids being converted to ammonia. As a result, more of the original feed protein is available for absorption by the animal, which can be used for energy and also as building blocks for building the animal's tissues, so the gain-to-feed ratio improves. It has a similar effect to antimicrobial growth promoters (which are still used as growth promoters in some countries, but are known to cause antibiotic resistance), "but unlike other growth promoters, it is a natural compound from a well-known forage." (Ref 65).

Also, interestingly, (talking about ammonia), the Woodland Trust says that "Trees have been found to be effective at intercepting and sequestering ammonia, either at source when trees are planted around slurry pits or livestock sheds, or when planted as buffers around sensitive habitats." (Ref 66). Livestock like to cluster under trees for shade and shelter and research has shown benefits to productivity in some parts of world when animals have this possibility. More standing trees in pasture land may have a range of advantages.

Tim May gave a talk to CFBoA in 2014, describing how he was returning the 2,500 acre Kingsclere Estate in Hampshire to mixed farming. After a decade of big arable farming the soils had become impoverished and crops had started to fail. After returning half of the land to grazing, which will be rotated with the arable crops, the soil food web started to improve and the soil darken as carbon storage in the soil resumed. Tim and other farmers describe on this website how they raise livestock on a natural diet of grass, wildflowers and herbs, and following the Pasture for Life ethos, where no grain is fed. (Ref 67).

At the first shared conference between the NFU and the Sustainable Food Trust on 5th July 2019 leading environmental scientists from Oxford University and Rothamstead Research, one of whom had served on the IPCC, said that "the accounting system, endorsed by Defra and our Government, and even the Committee for Climate Change , which ought to know better" for methane from ruminant livestock and the contribution of livestock to global warming, is flawed in a number of respects. Using different metrics, beef and lamb outperformed pork and chicken, both because of nutrient density (instead on weight of product/ unit of GHG) and because less cropland was required (much grassland is not well-suited to producing food for humans other than through grazing).

When carbon footprinting tools are used that measure the nutrient density of food/ drink products versus GHG emissions it gives a very different outcome to when the functional unit used is, for example, the weight or volume of product; and the tables would look different again if the functional unit used was a specific nutrient. See table below on beverages:

Beverage nutrient density v GHG emissions:

	Nutrient density	g CO2eq/g product
Milk	53.8	99
Orange juice	17.2	61
Soy drink	7.6	30
Oat drink	1.5	21
Red wine	1.2	204
Soda	0	109
Water	0	101
Beer	0	10

(Ref 68, Smedman et al, 2010)

So, which food/ drink looks like the most environmentally friendly option depends on what question researchers ask and which functional unit, or range of metrics, they use, and the metrics keep changing. (And it feels as if there are many questions still not being asked widely enough, as discussed throughout this document, around whole farming and food production cycles, which food production best maintains and enhances soil fertility and soil carbon storage; and the anomalies which occur around the allocations of emissions between coproducts, or byproducts, in carbon footprinting tools.)

'Climate Solution' – 'Grazing livestock brings benefits' is the article on the front page of the Farmers Guardian on 10th May 2019. It reports that Farming Minister, Robert Goodwill, says that "We need to look at how we feed cattle in a way which produces less methane and makes livestock production more sustainable, but using grazing as apart of rotational farming is part of the solution, not the problem." These comments followed shortly after the Committee on Climate Change report, which urged Government to reach net zero greenhouse gas emissions by 2050. The National Sheep Association chief executive said "The role of grazed grassland, rotational and permanent leys in building soil organic matter, soil biology and storing carbon is ignored. Many of the climate change assumptions regarding ruminant livestock farming are based on global production systems, which are different to mainstream methods in the UK."

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10) Land Use

11) Biodiversity

12) Food Loss and Food Waste

"The terms 'food loss' and 'food waste' have distinct meanings as they occur at different stages of the food value chain. 'Food loss' occurs before the food reaches the consumer as an unintended result of agricultural processes or technical limitations in the production, storage, processing and distribution phases. On the other hand, 'food waste' refers to good quality food fit for consumption that is consciously discarded at the retail and consumption stages." (Eat-*Lancet* Summary Report)

Wasted food uses nearly 3.46 billion acres of land - around 30% of the world's agricultural land area. It is not only wasted land use which is an issue, but also that the produce will be accumulating more and more unnecessary GHG emissions right up to the point of wastage: for working the land, agrochemicals, energy, transport, processing, packaging, wholesale and retail stage emissions, perhaps refrigeration, and so on; and beyond, for waste disposal management with probable associated methane emissions from landfill sites. Human effort is also wasted and the land used may have displaced wildlife and sometimes people. Irrigation may have been used consuming precious water resources.

A report by WRAP estimated the food waste at different stages in the UK supply chain in tonnes: retail 300,000; hospitality and food service 1m; manufacturing1.9m; primary production (farm stage, includes grading, packing and washing) 3.6m; household 7.1.

"More than £1bn of food destined for UK supermarkets is thrown away or fed to animals before it leaves farms every year, according to a study highlighting the scale of the country's waste problem. Crops rejected by retailers because they do not meet quality standards, fluctuations in demand or problems during storage or packing all contribute to 3.6m tonnes of waste in primary production, more than 10 times the amount thrown away by retailers, says a report by Wrap, the waste-reduction body. The figure includes 2m tonnes of surplus edible food that does not make it to a retailer or other intended buyer, but is diverted to feed livestock or distributed to charities. The rest is disposed of by being ploughed back into fields, composted or used to create energy." (GNS, Sarah Butler,25 July, 2019)
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13) Bioenergy

14) Conclusions

Document being compiled for Climate Friendly Bradford on Avon (CFBoA) as basis for discussion. To be further edited and completed.

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