ENVIRONMENTAL IMPACTS OF OUR FOOD AND DRINK: THE MISLEADING METRICS

Are the incomplete and anomalous metrics used to assess the carbon footprint of food misleading public policies and dietary recommendations?

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Overview

Large-scale reports on food, farming and the environment and national policies are being skewed by the incomplete metrics used to assess environmental impacts. The limitations of the measurements used, and the separate consideration of co-products, also compound the difficulty of developing a shared understanding of environmentally positive dietary choices.

The issues relating to sustainable food and drink are diverse and complex. Nearly all are key areas of public debate involving a wide range of personal views, often strongly held, and powerful vested interests. The shortcomings of the metrics used to assess the environmental impacts of our food and farming systems introduce distortions that act as barriers to reaching an understanding in common.

Farming takes place within a complex ecosystem. Many key aspects of sustainability, although acknowledged by scientists and statisticians as likely to be very important, are difficult to measure quantitatively and can have high levels of uncertainty. As a result, factors such as soil health, soil carbon storage and biodiversity are often omitted from the metrics. By omitting, treating separately, or failing to fully integrate these into analyses, the metrics become effectively invalid as measures of environmental sustainability. They serve the interests of the "productivist" model of industrial-scale farming and the global corporative food system, whilst undermining the case for mainstream adoption of less intensive agroecological systems, where food production can give rise to multiple ecosystem benefits.

A problematical area is that most major agricultural products have a range of co-products and by-products. The current measurement tools partition these, giving each a different carbon footprint (CFP) or life-cycle analysis (LCA). This obscures the relationship between products (for example, dairy products and dairy beef). This separation estranges us from whole cycles of food production and mires discussion and debate in perplexity.

While the nutritional quality of diet is crucial, sharing food and favourite meals with others has always been a central part of family interaction, social enjoyment, pleasure and well-being. For many reasons, therefore, it is important that we should consider whether the dietary advice advocating exclusions of certain food types for environmental reasons is sound, or a product of inadequate metrics.

Section A: Context – the metrics do not make sense

A low carbon footprint sounds as if it should be just what we need. However, all is not as it seems.

Key concerns:

The incomplete and anomalous nature of the carbon footprint (CFP) and Life Cycle Analysis (LCA) metrics used in the food system is skewing advisory and public policy documents, and dietary guidance for low environmental impact in carbon calculators. Eco-labelling of products may also use the same currently inadequate metrics. The metrics:

- frequently omit crucial aspects of sustainable production that are hard to quantify, such as: soil health, soil carbon storage, biodiversity, nutritional quality and sociological and economic factors, leading to reports and policies that segregate, rather than integrate, these factors
- nearly always show that more intensively produced food has a lower CFP and have become "drivers" of intensification, whilst failing to capture the positive aspects of less intensive systems
- often do not include the positive aspects of animal production
- partition the assessment/ values given to co-products, thereby obscuring their relationship, such as "dairy products" and dairy beef: this undermines sensible debate and decision-making
- create barriers to arriving at an understanding in common of sustainable food and farming, developing holistic policies and environmentally sustainable dietary choices

1. How the metrics are misleading us

With the urgent need for concerted action on climate change, environmental organisations, councils and others are increasingly promoting carbon calculators to encourage behaviour change. As a result of this, and other information/misinformation now prevalent in the public domain, people are often excluding some food types from their diet (not all with a sound knowledge of how to ensure a nutritionally replete intake).

CFP/LCA metrics have been adopted by those devising carbon calculators and the resulting scoring systems promote veganism, then vegetarianism, then very little meat as associated with the lowest carbon emissions. However, these metrics and calculators do not generally take into account factors such as the biological realities of farming systems, soil health, soil carbon storage, regenerative soil management, nutrient density and what our farmland can best produce without increasing our dependence on imports for key nutrients, as well as other important issues including food security. These crucial considerations may in fact be undermined by CFP/LCA metrics and the advice in carbon calculators. CFP and LCA may be very useful tools in some contexts, however they do not by themselves indicate the sustainability of a product or process.

Naturally, people are free to make their own choices about what they eat. However, food production takes place in a complex biological domain; and the metrics currently used to assess the carbon footprint do not generally take into account a range of aspects that are difficult to quantify, although they are extremely important.

There are positive aspects of animal production and negative aspects of crop production that are not currently reflected in the metrics, thereby misleading the public discourse on diet.

The misleading nature of the incomplete and anomalous metrics used by policy-makers and others is highlighted by Notarnicola *et al* in a European Commission – Joint Research Centre review: "In these assessments the positive aspects of animal production are often not included. These positive aspects, such as ecosystem services, soil fertility, use of resources otherwise not available as food, and low levels of pesticide use, are elements where the LCA approach today is generally weak."[1]

There is a lack of public transparency in that most consumers are probably not aware that the tools used to measure the CFP of food (most frequently now the LCA metrics) nearly always show intensively produced food as more carbon efficient. Adapted for use in agriculture from industrial measures, the tools quantify the efficiency of output in relationship to emissions. By failing to incorporate wider parameters of sustainability, these metrics are now driving intensification of farming and food production on the more-for-less basis. This does not sit well with widespread perceptions and evidence that intensive production is frequently part of the environmental problem in the food system. Are CFP/LCA metrics in fact "drivers" of intensification of farming? (See section B below].

The metrics misguide consumer perceptions by:

- not usually including the impacts of food production, for example on soil carbon or soil biota/ soil health
- considering food products separately from their co-products/by-products and sometimes allocating emissions on the basis of their relative monetary value
- assessing single products instead of the range of products from whole farming cycles, which keep the soil healthy and fit to feed future generations sustainably

Most agricultural products have a range of co-products and by-products: these are treated separately in CFP and LCA metrics and given different ratings. For example, advocacy of vegetarianism as more carbon efficient ignores the basic reality that, according to the United Nations (UN)[2], "meat production is a biologically inevitable co-product of the dairy production". About 50% of beef eaten in the UK is a by-product/co-product of the dairy industry: surplus calves from dairy herds are reared on for beef and culled cows are used for meat. Through the contrivance of the metrics, however, dairy products are given a much lower CFP rating than beef, which throws sensible discussion into perplexity**.** People often have the impression that "dairy foods" can be produced in isolation. Higher welfare dairy production increases the amount of dairy beef produced, as a result

of increased longevity and more calves being produced but which are not needed as dairy herd replacements - this is highlighted in the IDDRI report: 10 Years for Agroecology in Europe[3].

I am not aware of any land-use modelling for a vegetarianism-for-all scenario. How could there be? This scenario would lead to mountains of wasted meat. No wonder the disconnect between field and fork is a problem for farmers.

Intensive, industrial meat and dairy and monocultural crop production are all particularly problematic[4] [5]. This is not reflected in LCAs.

2. Soil organic carbon – specialist crop lands are running on low

There needs to be an awakening to move away from the assumption that plant-based foods are intrinsically environmentally innocent. This entrenched misconception is promulgated by the anomalies, and omissions of important factors, in the CFP/LCA tools. Plant foods are shown as having a much lower CFP than animal-sourced foods, even though legumes and pulses, grains, nuts, seeds, fruit, vegetables and plant-based fats and oils, and crops for drink production (and for other purposes) are produced globally at industrial scale: the result is agrichemical-dependent monocultures, many with degrading, thinning soils, a dearth of biodiversity below and above ground and marked loss of soil organic carbon (much cropland is running on low). In the UK, soil degradation and wildlife losses are particularly marked in the specialist arable south-east. This calls into question the validity of present CFP metrics in guiding environmentally responsible food choices. All foods need to be produced from sustainably managed soils and it seems vital to integrate a wider range of considerations into the metrics used in assessing the impacts of food production.

Most arable soils have lost 40–60% of their organic carbon. This established loss is not included in the CFP/LCA metrics or used in carbon calculators**.** Net annual removals of greenhouse gases (GHG) from the atmosphere are only reported in Land Use Change data (LULUCF). The Office for National Statistics (ONS) indicates that arable (crop) land loses carbon to the atmosphere and is a net source of greenhouse gases; by contrast, grassland is a net carbon sink[6], again not reflected in CFP metrics. It is difficult to capture the data reliably on a local basis and there are natural fluxes and variability and much is still poorly understood, according to researchers. Peatland farming, associated with land drainage – principally in the fenlands of south-east (the main horticultural area in the UK) - is documented as emitting large amounts of CO_2 leading to an adjustment of average figures in 2021 government documents. In CFP metrics**,** these are again key aspects where there is a lack of transparency regarding the environmental impacts of different foods.

3. Crop failures and food security

Among the most compelling reasons for not advocating a plant-only diet for all are the warnings from the UN and the Meteorological Office that "Governments may be seriously underestimating the risks of crop disasters occurring in major farming regions around the world" and that simultaneous harvest failures in key regions would bring global famine…. "We have found that we are not as resilient as we thought when it comes

to crop growing."[7] Such crop failures would also have a major impact on production of grain-fed meat. UK farmers can produce substantial amounts of very good first-class protein and other key nutrients, as well as biodegradable fibre such as wool, from well-managed grasslands. Although climate change will be increasingly challenging for livestock production, as well as for crops, livestock can sometimes cope quite well with conditions that can wipe out crop yields. Furthermore, grasslands can often recover quickly after extreme weather when conditions improve. Well-managed mixed farming benefits soil health; and, maintaining diversity of both plant-sourced and animal-sourced food production and consumption improves national and global food security and resilience.

4. Recognising the relationship between co-products

Palm oil and soya (or soy) oil are the two largest sources of vegetable oil in the world, with the valuable residues after extracting the oil mainly being used for animal feed. A soya bean crop produces 20% oil, 80% soya bean meal. Where is the discussion as to what will replace these plant-based (vegetable) oils, which are used throughout our food system and also in other products such as cosmetics, biofuels and industrial products, in order to reduce our dependence on soya and palm oil production and their environmental impacts? Truthful appraisal and understanding are clouded by the separate consideration of products and co-products in the current public narrative, in these and so many other instances.

Animal feedstuffs are very often a by-product of plant-based foods for humans, with the crop residues recycled as feed or bedding for animals. Biotically rich, composted manure, which can be spread back on the land, and dung deposited directly onto the land, improve soil fertility, structure and function – reducing the need for agrichemicals and increasing crop yields. Staple foods that can be locally produced and provide important nutrients have played a key role in keeping people healthy through the centuries and increase the sustainability and flexibility of farming systems. Such foods are perhaps being undervalued.

5. Dietary choices in relation to restoring soil health and biodiversity and locally adapted, diverse farming systems

Prof Michael Lee, deputy vice-chancellor at Harper Adams University, says "Our requirements for protein could all come from plants, livestock, or a sensible combination of the two."[8]

It is increasingly recognised that grassland and mixed farming and mosaic landscapes have multiple benefits for soil health, soil carbon storage, wildlife and other environmental goods (as well as landscape). The loss of locally adapted diversity of crops and livestock is now realised to be a threat to the health and resilience of our food systems. Soil health is particularly seen as a prime issue that needs urgently addressing – the vital role of regenerative farming with sustainable soil management has come to the fore, as crops have become more vulnerable to failure in degraded soils across the world while some grassland needs to be less intensively, and some more intensively, grazed for best environmental benefits.

"Purely arable farms belong to the 20th century… now we are seeing more and more the long-term detrimental effects of pursuing the chemical route [decreased yields, resistant weeds, soil erosion and flood

damage]. Farmers instinctively know that current practices aren't sustainable" according to Tom Chapman, head of Regenerative Agriculture at the charity Innovation for Agriculture in an article entitled 'Mixed farming is seen as holding the key to a brighter arable future'[9]. In 2020, data from more than 50 years of field studies at Rothamsted Research has enabled scientists to solve the mystery of why farmyard manure improves the soil and how the use of synthetic fertilisers over the last century has progressively drained the soil of carbon, altering the structure of soil's microscopic habitat and the genetics of microbes living within it[10] [11].

Principles of regenerative farming outlined by Groundswell are: 1. Do not disturb the soil. 2. Keep the soil surface covered. 3. Keep living roots in the soil. 4. Grow a diverse range of crops. 5. Bring grazing animals back to the land[12].

The mainstream farming press now has frequent articles about farmers adopting regenerative soil management approaches, such as cover crops, green manures, and minimum tilling. Additionally, the reintroduction of livestock into arable systems is resulting in marked improvements in soil and crop health and crop yields, whilst using far less agrichemicals. (At the same time, every farm is different: what works well on one farm does not always work on another – whether it be no-till/minimum-till, green manures or livestock.) Also, there is still much to be understood as to how restoration of soil organic carbon storage can be optimised, which is challenging on arable land. Farmers are welcoming the encouragement to integrate more legumes and pulses into their arable rotations. New varieties are being bred to thrive better in the UK climate; nevertheless, in some years crops do not achieve high enough quality for food, although they might be suitable for livestock feed. In the wet spring of 2020, it was not possible to plant some crops.

6. Where our protein is produced. Importing food and impacts on more vulnerable countries

Although consumption of more plant proteins is considered important for health benefits and to ensure consumption of animal-sourced products stays within environmental limits, it needs to be borne in mind that most of the high-protein, popular legumes/pulses and nuts are imported into the UK. Even though less than 1% of the population sign up to Veganuary, it triggers an increase in imported food, according to the BBC/Open University documentary series What Britain Buys and Sells in a Day (presented by Ed Balls, 2019). Food imports shift our carbon and ecological footprint for key nutrients to other countries, many of which are likely to be more vulnerable to climate extremes and water stress than the UK[13]. 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."

We are seeing now that our food supply system can be vulnerable in ways that many of us had not anticipated. For example: disruption to trade and labour caused by unexpected events (notably the pandemic);

changing and unpredictable international political and economic conditions and relations affecting business and trade; climate extremes affecting not only farming and food production, but also transport, electronic and communication systems.

The UK is probably better suited to reliably producing a diversity of first-class rather than second-class proteins, in contrast to warmer climes; and Notarnicola *et al* highlight that "in general, in countries with colder climates, the diets tend to involve high caloric consumption of dairy products and meat. This highlights the fact that assessment of dietary choices must take into account that many different factors arise when food choices are made including social and cultural ones."[1] Our farmers need to be producing the full range of key nutrients that we need for health to a significant level of national self-sufficiency for food security: 80% self-sufficiency, rather than the current 60%, is recommended by some food policy experts.

The benefits to food security of grass-fed animal foods still do not seem to be taken into account by those calling for deep cuts in ruminant consumption to cut methane emissions. Is it possible that such cuts would lead to "virtual" reductions in greenhouse gases in government statistics, rather than actual environmental gains in the "real world"? Agricultural methane contributes 5.4% of the UK's total GHG emissions [less if the more recent global warming potential (GWP) assessment tool GWP* is the measurement used]; over two-thirds of our ruminant meat is home-produced. This biogenic methane production, which is part of the natural carbon cycle, can be reduced by about 30% through a range of measures without decreasing the national herd, according to George Eustice, Secretary for State for Environment, Food and Rural Affairs[14]. Dung and urine from well-managed, grazing ruminants help kick-start the vital soil carbon cycle and nitrogen cycle, as well as supporting biodiversity and carbon capture.

Restoring soil carbon storage and soil health in farmed soils are surely some of the most important things we can do to mitigate climate change and ensure future food security. Mixed farming also decreases the fossil fuel requirements of arable production by supplying manure as fertiliser.

How serious are we about cutting fossil fuel emissions?

During lockdown, GHG emissions from air flights were reported to have decreased by 5% globally: these emissions are true GHGs, which continue to accumulate in the atmosphere over the long-term, as opposed to the biogenic methane produced by ruminants, which does not persist over the long-term and most of which is broken down and reabsorbed within about twelve years. However, in spite of the extreme seriousness of the climate emergency, there is no meaningful emphasis on radically cutting travel or transport, even though these are the largest sources of GHG emissions (27% of UK total)[15]. The fossil fuels needed to source materials and produce and maintain the necessary massive infrastructure of steel, tarmac, cement, concrete and so on are not included in the statistics for this sector. Furthermore, international travel and transport emissions are not even included in national statistics (see extracts with ref 15 below); and now we are increasingly trading further afield. There is a lack of accountability here. It seems that the more we trade internationally the less responsibility we are required to take for the emissions, and other environmental impacts, of our consumption.

7. The environmental implications of food waste are under-represented in government statistics

Waste management is included in the UK national statistics. However, the gigantic total emissions (across all sectors) associated with wasted food, are not identified. Food loss and waste accounts for a third of all food produced. This has been estimated to equate to the produce of 3.46 billion acres of land globally – around 30% of the agricultural land area. It is not only land use that is wasted, but also the wasted food will accumulate more and more unnecessary GHG emissions right up to the point of wastage: for working the land, agrichemicals, energy, transport, processing, packaging, wholesale and retail stage emissions, perhaps refrigeration, and so on; and then for waste disposal management with probable associated methane emissions from landfill sites. Human effort is also wasted and the land used might have displaced wildlife and sometimes people. In some cases, irrigation will have been used, consuming precious fresh water resources.

8. How to feed well the projected 2050 population, whilst reducing environmental harms

The International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD, 2008) report, following four years of research globally by 400 scientists from different disciplines, recommended a central role for agroecology in environmental sustainability, integrating food production with restoration of nature: "supporting agroecological systems, and enhancing biodiversity conservation and use at both field and landscape scales; promoting the sustainable management of livestock, forest and fisheries; improving understanding of the agroecological functioning of mosaics of crop production areas and natural habitats; countering the effects of agriculture on climate change and mitigating the negative impacts of climate change on agriculture."[16] Serious global losses of diversity of food crops and livestock breeds are highlighted.

In an interview in 2016[17], Prof Hans Rudolf Herren, co-chair of the IAASTD, refers to "The need for a radical reset towards sustainability in all three dimensions, environmental, social and economic… What has been most ignored is the need to also radically transform industrial food systems… It is now imperative that [the UN's Sustainable Development Goals] are implemented without delays focusing on the food system, sustainable agriculture and agroecology… Much too little importance has been given to agriculture and food systems to address climate change, in particular when it comes to mitigation… we also need to reduce the amount of carbon already in the atmosphere if we want to have a small chance of keeping global warming below 2°C… Climate-Smart Agriculture could also be called Green Revolution 2.0. It is just more of the same old model some want to maintain given the huge vested interests that agribusiness has in selling inputs to farmers, be it seeds, fertilizers or precision agriculture gadgets. With all we know about the need for holistic and systemic approaches to agriculture, this is clearly wrong-headed and diverts too much attention from what needs to be done, i.e. embracing agroecological/regenerative practices. The latter two are going hand in hand, as the basic premise is to work with nature, not against it, using natural processes to regenerate soils and seeds and work in highly diversified systems, with diverse crops and animal breeds of very distinct genetic makeup… The truth is that it is irresponsible not to spend money to transform the system now to agroecological and regenerative practices and science. In its Green Economy Report in 2011, UNEP clearly demonstrated that

IAASTD's recommendations can be implemented by 2050 with spending only about a third of the total agricultural subsidies paid today. We would still produce enough food in the quantity and quality needed to nourish well nine to ten billion people, while using less land and water."

An agroecological model of food production in Europe (and the UK), according to the IDDRI report, can produce a nutritious diet for the projected 2050 regional population with appropriate dietary adjustment, without recourse to intensive farming or lab foods. The agroecological modelling used by IDDRI values mixed farming and the contribution of our grasslands as pivotal to overall food security, rural communities, regeneration of soils, ecosystems and biodiversity, healthy water systems, carbon sequestration and climate mitigation. It also factors in the need to diminish the negative impacts in other countries of production of our imported food, drinks and animal feedstuffs. I agree with its authors' concern that many reports and national strategies do not integrate these essential components of sustainable food and farming and wider environmental impacts into their analyses: among such reports I would include the Agriculture Act, the Climate Change Committee's (CCC) 6th Carbon Budget and the National Food Strategy (NFS) Part 2. Although all these documents have many very interesting and laudable elements, I would suggest that all draw too heavily on incomplete metrics and separate out those factors that are hard to measure. This leads policy and recommendations away from the rapid transition of all farmland to the multi-functionality of an agroecological approach and towards a partitioned approach to land use, which includes intensive production and strong advocacy for technological innovation and novel foods. The NFS recommends creating a "three-compartment model", identifying land for food production, land for nature/carbon sequestration and land for low-intensity farming.

The NFS says "Providing an abundance of healthy and sustainable food will require innovation… Such innovation would have economic benefits, boosting the UK's involvement in emerging technologies such as gene editing, synthetic food production, nanotechnology, microalgae bioreactors, the internet of things (IoT), robotics and sensors, 3D food printing, and artificial intelligence." The Agriculture Act includes provision to support fast-tracking of such innovations. We are into unknown territory here regarding impacts on human and animal health and the knock-on impacts for farming, for the environment and for rural communities of such a transition. Could lab meat, and other novel proteins and foods, in fact undermine regenerative farming, the restoration of carbon to our farmed soils, the recovery of farmland biodiversity and the connection of our food with the land – with the earth?

9. How much meat per capita is compatible with a healthy dietary intake and environmental sustainability?

Most major reports on the environment, food and farming do not, in fact, advocate exclusion of meat or dairy products from the diet – so in this respect carbon calculators are not well aligned. The need to reduce total global meat and dairy consumption is clear. However, key questions are: who needs to reduce consumption, by how much, and which products? These are all important questions and reports vary in their

recommendations. The present blanket message in the public domain to reduce meat and dairy consumption has numerous downsides and is not appropriate for all. A new, more nuanced public narrative is needed with clearer information on appropriate levels of intake.

Agroecological production, according to the IDDRI report, could enable a dietary intake of moderate amounts of meat: 92 g/day (or 650 g/week) per person of cooked meat; rather than the very small amount identified by the EAT–*Lancet* report. Poultry consumption has more than quadrupled over the last 60 years in the UK, whereas beef and lamb consumption has been in steady decline. The IDDRI report recommends substantial cuts in consumption of poultry, eggs and pork products [to de-intensify production and because of the direct competition by granivores (seed-eaters) for cropland which could be used for food for human consumption], rather than significant reductions in grass-fed, ruminant meat. A moderate reduction in dairy products is recommended. Moderate amounts of meat and dairy products are identified in the UN dietary guidelines for low environmental impact[18]. These guidelines are consistent with health advice from the NHS (reviewed July 2021)[19] and the Association of UK Dietitians[20] on the moderate levels of meat consumption that can constitute part of a healthy diet, including up to 70 g/day (or 500 g/week – cooked weight) of red meat. Those who regularly consume more than 90 g/day of red meat are advised to reduce to 70 g/day. This gives better guidance than a generalised message to all to reduce meat consumption. Per unit of nutrient density, pig and poultry systems occupy 3.6 - 5.1 times more arable land respectively than sheep or cattle[21]. Most of our beef is produced in the UK and is mainly grass-fed. It is a shame that so many people seem to perceive all beef production as being from intensive feed-lot production or rain forest destruction, when here it is largely a key component of environmentally-friendly (and small-scale family-friendly) farming. Minette Batters, NFU President, said recently that average UK beef herd size is 30.

10. Healthy nutritional intake, nutrients in foods and highly-processed foods

It is clear from varied traditional diets that it is perfectly possible to live a long and healthy life on a wide variety of diets, as long as they are nutritionally balanced and healthful. The inclusion of plenty of plant foods and unprocessed or minimally processed foods are considered to be key components.

According to the NFS Part 2, "Two-thirds of the population eat less than the minimum recommended level of fruit and vegetables and a third eat more than the maximum recommended level of red and processed meat. Across the population, we would need to increase our fibre intake by 50% and cut our consumption of sugar, salt and saturated fat by 12–40% to meet the recommended levels." It presents the evidence that "Over half of our diets in the UK are ultra-processed; higher ultra-processed consumption is associated with weight gain [and] ultra-processed foods are strongly associated with disease." Henry Dimbleby's proposed tax on sugar and salt in the NFS invites reformulation of ultra-processed foods (UPF) by manufacturers. However, he does not highlight that sugar, salt and fat are added to compensate for the loss of nutrients, structure and, thus, flavour of the food associated with the high level of processing and that this also necessitates the addition of many non-food additives[22]. Perhaps it is the UPFs that are a problem, not just the added salt, sugar and fat? There has also been a diminution of micronutrients in food at primary production level over the last century[23].

There might be a range of reasons for these findings. Wheat is an important source of minerals such as iron, zinc, copper and magnesium in the UK diet and links between high-yielding cultivars and decreased mineral concentrations have been observed[24]. These are critical issues and the corporative food chain, which drives industrial scale and specialised farming and the endless innovation in UPFs, has a poor track record here.

Van Vliet *et al* (2021) raised important issues regarding the under-researched health outcomes from changes in the ways in which our traditional foods are produced[25] and research by Weir *et al* found that milk and meat from cows that grazed through at least part of the year contain more vitamin D than those in zero-grazing dairy systems; vitamin D levels were also found to be related to the breed of cow[26].

Better food more equitably available is needed. There needs to be more focus on the full range of nutrients needed for a varied, healthy diet from sustainable sources, rather than the almost exclusive focus on whether our protein intake is animal- or plant-sourced.

11. Land use, biodiversity and sequestering carbon

The CCC's 6th Carbon Budget states that "cropland and grassland should not be treated equally. In some regions, crops and livestock farming do not compete for the same land, as many grassland areas (e.g. the uplands) are not suitable for crop production." Interestingly the ONS says that a 15% decline (between 1998 and 2014) in sole right rough grazing used for low intensity farming is likely to lead to a reduction in carbon sequestration and other regulating services from farmland in the UK (see extracts in ref 27).

As climate change takes its toll on food production worldwide, substantially retaining our grasslands would surely be wise. They can produce high-quality, first-class protein and many other important nutrients (in bioavailable form), and other products including fibres, as well as reducing the need for agrichemicals on croplands. It is particularly the farmland specialist species of plants and wildlife that have shown the most marked declines. The ONS identifies the reasons for the decline in specialist farmland birds (see extracts in ref 27). Many generalist species also use farmland. The multi-functionality that can be achieved with an agroecological, restorative, land-sharing approach to food production, biodiversity, carbon capture and tree planting might have wider ecological benefits than large-scale land sparing and partitioning of land use.

Any food we can produce sustainably here takes pressure off land and water resources in other countries. Much more fruit and vegetables could beneficially be produced in the UK, if as consumers we choose home-grown produce and reduce reliance on out-of-season and exotic produce.

The increasing competition between food and fuel for land is worrying. With increasing uncertainties associated with climate change, this does not seem to be a sensible time to be significantly diminishing the utilisable agricultural area and losing the land's food-producing capacity. We already import 40% of our food.

12. Woodland on farmland, and associated eco-systems benefits, to be allocated to farmland in future ONS Natural Capital updates. The value of grassland, mixed farming, agroforestry and mosaic landscapes. Multi-functionality or partitioning of land use? The Welsh Government leads the way.

At present, woodland areas of over 0.5 hectares on farmland are included in the National Forestry Inventory and amount to over 28% of the total forest area. According to the ONS (2016), "farm woodlands, together with the [potentially significant] ecosystem services provided by these woodlands, have been excluded from the farmland ecosystem accounts."[27]

The benefits of the tapestry landscape that farmland can provide are thus currently undervalued in the data. Over 28% of the ecosystem benefits allocated to forestry alone are, in fact, attributable to farmed systems. This suggests that in the national debate regarding the benefits of widespread afforestation the benefits to ecosystems of extensive forestry are being overrated, with a commensurate undervaluation of the ecosystems benefits of woodland integrated within farmland in mosaic landscapes (where multiple benefits to food production, biodiversity and carbon sequestration can combine).

In correspondence, Adam Dutton, ONS, indicated that "Within Natural Capital accounts the original intention was to break up the country into discrete broad habitats and then assign asset values to each. This led to discussions over whether a bog in the uplands should count in the Mountain Moorland and Heath or Wetland accounts. In any future update of the 'farmland accounts' for natural capital, any habitat within the farmed landscape would count towards farmland – just as a walk along a cliff will count towards their marine account. This means that the separate asset accounts cannot be added together to yield the whole but will make more sense in terms of policy interpretation."

Agroforestry has much to offer and "can sequester carbon in the biomass and soils, improve water quality from reduced nitrate leaching into water courses, improve soil structure and fertility from litter fall, increase livestock welfare and enhance biodiversity", according to the CCC's 6th Carbon Budget.

Partitioning or integrating matters… and economic sustainability

The Agriculture Act has substantially separated its provisions for agriculture from ecosystems, biodiversity, water and the health of the nation, according to Prof Tim Lang, Food Policy, City University.

It is helpful at least that pressure for soil health to be included as a 'public good' has prevailed and that natural capital in any habitat within the farmed landscape will count towards farmland accounts in future ONS updates.

"The Welsh Government has recently adopted Sustainable Land Management in its land management strategy. The ambition is a transition towards landscapes that are multifunctional. This means that they:

produce healthy food; protect wildlife; provide clean water; help to address climate change; provide protection from hazards; and they reflect cultural heritage values."[28]

Farming has an amazing potential to increase the natural carbon sink and at the same time mitigate climate change in so many ways – and much exciting change is happening – but as consumers we need to support more fully what our farmers locally/in the UK can produce in healthy, integrated systems. To have the time, money and energy to focus on the environmental and ethical aspects of farming and growing, businesses need to be financially sustainable. Much farmland is now being bought up by lifestyle and private investors and, increasingly, by large corporations for rewilding, afforestation and to offset their carbon emissions. They can outbid farmers. Some farmers are being pressurised to sell. The future of our food supply remains open to question.

Section B: Incomplete and anomalous carbon footprinting and Life Cycle Analysis metrics are central confounding factors in policy-making with regard to environmentally-friendly farming and dietary advice: round-up of key points

a) Agroecological production is perceived by many individuals and environmental organisations to be better for the environment and this is supported by evidence, including from the IAASTD (2008) and the IDDRI (2018) reports. The benefits are likely to be incremental on multiple fronts.

Although a low carbon footprint sounds as if it should be just what we need, it seems that the currently used CFP and LCA metrics nearly always show that intensively produced food is more carbon efficient. 'Reducing the Emissions Intensity of Livestock Production: Case Studies of Success - Canada'[29] is an example of increased productivity of beef through use of anti-microbials and early transfer of young animals to feedlots in Canada being justified as more carbon efficient. This should ring alarm bells that not all aspects of sustainability are being taken into account.

The metrics seem to be drivers of intensification on the more-for-less basis. Do they, in fact, serve the interests of the productivist model of industrial-scale farming and the global corporative food system, and undermine the case for agroecology? Van der Werf *et al* (2020) in 'Towards better representation of organic agriculture in life cycle assessment'[30] say "Current LCA methodology and studies tend to favour high-input intensive agricultural systems and misrepresent less intensive agroecological systems such as organic agriculture" and "Meta-analysis of many field observations has shown that organic agriculture supports biodiversity levels, measured as species richness, that are approximately 30% higher than those of conventional agriculture, a result that has remained robust over the last 30 years." Co-author, Dr Knudsen, also gave a speech at World Soil Day, AU Foulum, Denmark in 2019 on the 'Life cycle assessment and soil carbon' (see summary with reference 30).

The current metrics, which omit hard-to-measure components even though these may be critically important, result in key incongruities of perception and difficulty in reaching a common ground of understanding in the debate on what is environmentally-friendly food production. They have led to agroecology and nature-friendly farming being treated as an added extra on the periphery of 'serious food production' in the Agriculture Act, the CCC's 6th Carbon Budget and in the National Food Strategy part 2, rather than integrated throughout the agricultural system as the IAASTD recommended.

b) Life Cycle Analysis was derived from analysis of industrial processes and has significant shortcomings when applied to agricultural products, which are produced in a complex biological domain and are associated with complex food chains, according to UN documents. Also, "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."[2]

c) In 2019, the UN called for "more ecosystemic approaches to be applied to the analysis of carbon balances in agricultural systems worldwide. The challenge is to fully account for both negative and positive effects of agricultural activities on climate change."[31]

d) These ecosystem parameters are missing from the accounting systems widely used in national policy reports and planning (as well as the dietary components of carbon calculators). Poore & Nemecek[32], for example, assessed the effect of foods on climate-warming GHG emissions and the amount of land and fresh water used across all stages of their production, including processing, packaging, and transportation. It is worth noting that the CCC says that cropland and grassland should not be treated equally. Furthermore, many aspects are lacking from the metrics used, including: soil health and biodiversity below and above ground; soil carbon storage; whole farming cycles that keep soil healthy and carbon in the ground and produce food with high nutrient levels. It is very questionable whether post-farm-gate emissions should be included in the carbon footprint of unprocessed foods or documented separately from the agricultural stage; and, in any case, they do not fully reflect many of the emissions and impacts associated with transportation. Nevertheless, the research by Poore & Nemecek, and others using similar approaches, are widely used by policy-makers and advisors (including the CCC, the NFS and Eat–*Lancet* and in carbon calculators), giving skewed outcomes.

e) The Global Farm Metric[33] being developed by the Sustainable Food Trust and partner organisations encompasses a more holistic assessment of the farm stage of food production, which hopefully will lead to a better informed, more balanced public narrative on sustainably produced food and make it easier for retailers, consumers and the hospitality sector to make better choices, as well as informing public policy. "The categories of assessment are: • Soil • Water • Air and climate • Biodiversity • Energy and resource use • Nutrient management • Plant and crop health • Animal husbandry • Social • Human • Productivity." We need to know that all of our food is well-produced in healthy, whole cycles of production that are environmentally and socially sustainable.

f) According to the Office for National Statistics[6], "The carbon stored in UK soils is by far the largest component of the biocarbon stock, containing approximately 94.2% of the total. The amount of carbon stored in UK terrestrial vegetation was considerably lower, containing 5.8% of the total... croplands are a net source of carbon to the atmosphere, whereas grasslands are a net biocarbon sink" However, this is not reflected in the CFP/LCA of food. Interestingly the ONS says "Carbon contained in animals living within the ecosystems, as well as inorganic carbon stocks contained in soils, have also been excluded from current estimates."

g) Single-factor carbon footprinting tools give very different results depending on the functional unit used (for example, weight of product vs GHG emissions or nutrient density vs GHG emissions) and there is a lack of clarity and consistency in the functional units used and range of factors included in LCA research which makes comparisons and meta-analyses difficult.

h) Most agricultural products have a range of co-products and by-products. The current measurement tools consider these separately giving each a different CFP, thereby obscuring the relationship between products (such as dairy produce and dairy beef) and increasing the disconnect between consumer/researcher/policy-maker and whole farming cycles of food production.

i) Allocations of GHG intensity between products, co-products and by-products are sometimes based on relative economic value**.** This is surely misleading when comparing relative environmental impacts.

j) The short article referred to earlier by Prof Michael Lee, Deputy Vice-Chancellor of Harper Adams University, highlights some of the anomalies and variability inherent in current metrics and how there is ongoing discussion on these issues, including developing a more appropriate way of assessing the impacts of biogenic methane than currently used, and finding a sensible balance between plant-based and animal-sourced foods. "Soil needs organic matter, and one of the best methods for its delivery is returning livestock manure to support arable crop production. This will not only improve crops yields, but also reduce fossil fuel use, as we will need less inorganic fertiliser for arable systems… A vegan diet may use land less efficiently than an omnivorous diet, as livestock can use by-products and land not suitable for growing crops"[8].

k) This highly relevant European Commission – Joint Research Centre document 'The role of life cycle assessment in supporting sustainable agri-food systems: A review of the challenges'[1] crucially highlights many of the shortcomings (still) present in LCA with regard to agri-food systems and includes the Role of Changes in Diet (section 6.2):

"Many LCA studies (e.g. Muñoz et al., 2010, Meier and Christen, 2012, Heller et al., 2013) have shown that the dietary choices of the consumer significantly affect the environmental sustainability of food consumption. Perhaps the most prevalent insight that emerges is that vegetarian diets seem to generate less environmental burdens compared to animal based ones, and also that the domestic/use phase is not necessarily negligible in terms of environmental impacts (Foster et al., 2006, Hallström et al., 2015). However, in these assessments the positive aspects of animal production are often not included. These positive aspects, such as ecosystem services, soil fertility, use of resources otherwise not available as food, and low levels of pesticide use, are elements where the LCA approach today is generally weak (see Sections 4 Modelling issues specific to agricultural systems, 7 Modelling food waste with LCA). Furthermore, replacing the essential nutrients of animal-based foods poses nutritional challenges (Millward and Garnett, 2010). As indicated by Heller et al. (2013) and by Smedman et al. (2010), environmental assessment of a diet cannot consider only the daily intake of food or its fat, energy or protein content, but must also comprise other more qualitative aspects of a diet. LCA of dietary aspects and health issues must consider more particularised and inclusive nutrition-based functional units (Stylianou et al., 2016)."

l) A large-scale meta-analysis by Rachel Bezner Kerr *et al* 'Can agroecology improve food security and nutrition? A review'[34] found that "A majority of studies (78%) found evidence of positive outcomes in the use of agroecological practices on food security and nutrition of households in low and middle-income countries. Agroecological practices included crop diversification, intercropping, agroforestry, integrating crop and

livestock, and soil management measures. More complex agroecological systems, that included multiple components (e.g., crop diversification, mixed crop-livestock systems and farmer-to-farmer networks) were more likely to have positive food security and nutrition outcomes."

Section C: Dietary Recommendations from the UN Food and Agriculture Organisation (FAO), 2016

These FAO/Food Climate Research Network (FCRN) guidelines for healthy diets with low environmental impact make more sense than current carbon calculators:

"There is increasing evidence that dietary patterns with low environmental impacts are also healthier. Common features of such diets are:

- the diversity of foods eaten
- a balance between energy intake and energy expenditure
- the inclusion of minimally processed tubers and whole grains along with legumes, fruit and vegetables
- meat, if eaten, in moderate quantities.
- healthy diets also feature dairy products in moderation, unsalted seeds and nuts, small quantities of fish and aquatic products, and very limited intake of processed foods that are high in fat, sugar or salt and low in micronutrients"

The British Government Buying Standards add further positive recommendations about priorities for sourcing more sustainable food:

- Seasonal produce
- Seafood from sustainable sources
- Fairly traded produce
- Food produced to high environmental standards, such as organic or integrated production (eg LEAF - Linked Environment and Farming)
- High animal welfare
- UK or equivalent production standards

Section D: Conclusions

The UN/FCRN dietary guidelines and Government advice on sustainable sourcing are a better basis than current carbon calculators for guiding food choices to provide well-balanced nutrition with low environmental impacts, whilst being adaptable to the individual's dietary preferences.

The pre-occupation with dietary exclusions has hijacked the narrative on food and the environment. This relates directly to the currently misleading metrics. There are powerful vested interests who are strongly pushing this agenda in the public domain and capitalising on the anomalous and incomplete nature of the carbon footprinting/LCA metrics. This creates a major distraction from addressing the issues of how to achieve high environmental, ethical and animal welfare standards for all food and drink, home-produced and imported, with less negative environmental impact. Biodiversity loss and sustainable soil management are both matters of global concern. Land use change for a range of purposes, the impacts on land and water resources abroad of our imported plant-based food and drink and industrial-scale monocultures are being largely ignored. A key UN recommendation that healthy, environmentally-friendly diets should include very little highly processed food is not yet being adopted in the UK. Transport impacts are under-represented. Energy use and how that energy is produced – from food and drink production to consumption stage – is critical. And crucially, a third of food produced is wasted, which generates more and more wasted greenhouse gas emissions the further along the food chain that waste occurs, along with the waste of land and labour.

Whole healthy systems of food production are needed, which enable farmers and producers to maintain or restore living, fertile soils and promote carbon storage, whilst at the same time producing nutritious food and promoting the recovery of farmland biodiversity. The benefits of including two portions a week of fish/seafood, including a portion of oily fish, in the diet has been highlighted by the ZOE report; however, the restoration and protection of marine and freshwater environments and fish stocks also need a high priority.

Policy recommendations, carbon calculators and carbon footprint/eco-labelling of products based on incomplete and anomalous metrics might lead to statistical advantages on spreadsheets, rather than environmental benefits in the real world, by disregarding or treating separately important aspects of sustainability that are difficult to measure quantitatively. A greater recognition of the shortcomings of the current metrics for the assessment of environmental impacts of food and farming is needed. We are not seeing the whole picture: it is as if a jigsaw has been taken apart and then reassembled with some of the key pieces left to one side. This creates dichotomies, polarised viewpoints and difficulty in reaching an understanding in common of sustainable food. In view of the present inadequate state of the metrics, it seems vital that food sections of carbon calculators are removed in their present form as a matter of urgency. For better outcomes, making active use of the UN and government guidelines or drawing on the work of the Sustainable Food Trust's Global Farm Metric would be helpful. These issues also need to be at the forefront of the thinking in any carbon labelling of foods and in national policies.

Ros Edwards 24th November 2021 (last minor amendments/clarifications 15.02.2022)

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This document is unfunded and independent. The conclusions, regarding the inability of currently used metrics to appropriately guide food and farming policy and dietary choices for best environmental outcomes, are based on several years of unfunded, independent exploration into sustainable food and farming and the related literature for Climate Friendly Bradford on Avon. The following documents question the prevailing public narrative on a number of fronts:

- Sustainable Food and Drink – Looking after the Earth
- 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?

Climate Friendly Bradford on Avon handouts:

- Dietary recommendations for reducing environmental impacts and improving sustainability
- Food for Thought

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See section 2 + section: 6.2, Role of changes in diet

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Extracts: "In 2019, 27% of net greenhouse gas emissions in the UK were estimated to be from the transport sector, 21% from energy supply, 17% from business, 15% from the residential sector and 10% from agriculture. The other 10% was attributable to the remaining sectors: waste management, industrial processes, the public sector and the land use, land use change and forestry (LULUCF) sector. The LULUCF sector includes both sinks and sources of emissions."

"Transport
Emissions from road transport, domestic aviation, railways and domestic shipping. Only includes emissions from vehicles and not from transport related infrastructure or from air conditioning. International aviation and shipping emissions are not included in national totals.

Agriculture
Emissions of greenhouse gases from livestock, agricultural soils (excluding carbon stock changes which are included in the LULUCF sector) and agricultural machinery."

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[Footnote – Scarborough P. *et al* (2014): "high meat-eaters (> = 100 grams/day), medium meat-eaters (50-99 g/d), low meat-eaters (< 50 g/d)". 'Dietary greenhouse gas emissions of meat-eaters, fish-eaters, vegetarians and vegans in the UK' *Climatic Change,* 125, 179-192 https://pubmed.ncbi.nlm.nih.gov/25834298/ [This research on the GHG emissions of different dietary intakes uses LCAs which omit many of the important, wider considerations of sustainability discussed above.]

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Extract: "Here, we present a new set of quantitative evidence to demonstrate that, per unit of overall nutrient value supplied by a given commodity, the demand for land suitable for human-edible crop production is considerably smaller under ruminant systems than monogastric systems, and consistently so at both farm and regional scales… Our results reiterate the risk inherent in an excessively climate-focused debate on the role of livestock in human society and call for more multidimensional approaches of sustainability assessment to draw better-balanced policy packages."

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Further extracts: "Woodland: The June Survey finds there to be 897,000 ha of woodland on farmland in 2014. These areas are potentially significant providers of ecosystem services; however, they are currently also included within woodland ecosystem accounts. This is because the National Forest Inventory (NFI), the source for the woodlands ecosystem account, contains all woodland if larger than 0.5 ha. In order to be consistent with other accounts, farm woodlands, together with the ecosystem services provided by these woodlands, have been excluded from the farmland ecosystem accounts." (The ONS UK Environmental Accounts indicate that the Woodland area was 12.8% of total UK area in 2015: 3.16 million hectares.)

"Figure 2 [see website] depicts the change in specialist farmland bird population between 1970 and 2013, compared with generalist bird population. It shows a clear decline in specialist bird population since 1970

believed to be primarily caused by the intensification of farming over that period. In particular, the loss of mixed farming, a move from spring to autumn sowing of crops, a change in grassland management, the increased use of pesticides and fertilisers and the removal of non-cropped field margins such as hedgerows have affected specialist bird populations."

"Rough grazing: Land used for 'sole right rough grazing' declined 15% between 1998 and 2014,reducing by almost 700,000 hectares. Rough grazing is used for low intensity farming and by avoiding negative environmental impacts of intensive farming, benefits from regulating services are expected to be more significant. The large reduction in sole right rough grazing is likely to lead to a reduction in carbon sequestration and other regulating services from farmland in the UK."

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Also: Knudsen, Marie Trydeman (2019) Life cycle assessment and soil carbon. Speech at: World Soil Day, AU Foulum, Denmark, 5 December 2019
"**Summary** The presentation discusses how to estimate climate and environmental impact from food and agricultural products using life cycle assessment. One of the impacts seldom included in LCA is soil carbon sequestration that can be included in the climate impact category. It is an important impact to include since some agricultural systems have a potential to capture more carbon than others, e.g. grass-based systems. Another impact category that is seldom included is soil quality. More research is needed to be able to include the effects on soil quality in LCA."

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