The carbon footprint of food

There is understandably a lot of interest in how much our food choices affect our carbon footprint. There are, of course, many other issues associated with agriculture – for example how to feed an increasing population, soil erosion, loss of bees, desertification, depletion of aquifers etc. - many with indirect implications for climate change.

Often food is discounted as a source of greenhouse gases (GHGs) because the carbon and energy contents of food come from the atmosphere and the sun, and consuming food ultimately just returns the carbon to the atmosphere, either through respiration (breathing) or decomposition.

GHGs, principally carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), are generated by all agricultural systems, however natural they are, but modern agricultural practices increase their production per unit weight of food far beyond the capacity of natural processes to remove them. Each gas has a different global warming potential (GWP) compared with carbon dioxide, with CH_4 calculated, without climate-carbon feedbacks, as being 28 (84) times as powerful, and N_2O around 265 (264) over 100 (20) years (Myhre et al., 2013) Based on this, emissions are normally quoted as 'CO_2 equivalent' or CO_2(e). FAO (n.d.) has estimates of total world GHG agricultural emissions while the IPCC (Smith et al., 2007) give some figures for worldwide agricultural methane and nitrous oxide emissions. The EPA (2016) estimates that 24% of all GHG emissions are from agriculture, forestry and other land use (including changes in land use). The European Union (n.d.) estimates world total emissions from all man-made sources as being around 54 gigatonnes of CO_2(e) in 2012.

The CO_2 associated with food production comes primarily from the burning of fossil fuels to create energy for farm machinery, food processing plants, refrigeration, transport, heating greenhouses and polytunnels, fertilizer production, and the mining of phosphates. Further CO_2 is released, along with CH_4, due to land use change when stored carbon may be released from organic matter in the soil – for example when forest is cleared to grow food for cattle, or when sheep trample peatlands causing the carbon to be lost to the atmosphere by microbial action. Large amounts of CH_4 are also released by ruminant animals such as cows and sheep through enteric fermentation, and by rice production due to the flooding of paddy fields. Nitrous oxide is released both from high temperature burning of fossil fuels such as vehicle engines and by specialist bacteria in the soil processing nitrogen-containing compounds such as unused nitrates from fertilizer and animal urine.

Calculating emissions is clearly complex and can vary hugely for any single food item. Various types of analysis are undertaken including 'life cycle analysis' – for example, the table below, using data from the US Environmental Working Group, EWG (2011), shows the estimated 'lifecycle' GHG emissions per kilogram of food consumed for various food types. This gives a flavour of the different emissions, although different sources of information do give different results. Clearly there are many variables, such as transport.

Total Emissions of Various Food Types consumed in the USA, including production, transport, retail, cooking, waste disposal etc

Food	Kg of CO_2 (e) per kg consumed
Lamb	39
Beef	27
Cheese	14
Pork	12
Farmed Salmon	12
Chicken	7

Food	Kg of CO_2 (e) per kg consumed
Eggs	5
Potatoes	3
Rice	3
Yogurt	2
Milk	2
Lentils	1

Some areas of the greatest interest are:

- The relative carbon cost of eating meat.
- The carbon cost of food transport.
- The relative carbon cost of organic vs non-organic production
- Whether sheep raised on hillside pasture avoid the typical carbon cost of mutton and lamb production.
- Whether it is better to eat in pubs and restaurants, eat ready meals or cook at home.
- Eating local meat vs. being vegetarian (or vegan)

The subjects of meat and food miles were covered by previous WinACC reports. In brief, eating less meat, eating seasonal food and avoiding air-freighted food are useful and effective ways to reduce one's carbon footprint.

Organic vs conventional farming

There is much conflicting evidence here. Bos et al. (2014) concluded that the GHG emissions of organic milk production were 5-10% lower than those from conventional farming, while for arable crops and vegetables organic emissions were 0-15% and 35-40% higher respectively. However, a DEFRA-funded study (Williams et al., 2006; Table 3) suggests that organic milk has a 20% **higher** global warming potential than conventional milk, while wheat and rape seed are similar for both systems and potatoes are 10% lower for organic. Venkat (2010) discusses some of the issues, suggesting that many inputs are common between systems and while organics benefits from the lower carbon cost of fertilizers and pesticides for example, conventional farming can benefit from economies of scale (although no references for these assertions are provided).

Many studies suggest higher CH_4 emissions from grass-fed compared to grain-fed cattle, but it is often unclear how much account has been taken of grain production emissions..

Carbon footprint of sheep grazing on hills

Because grazing on, for instance, Welsh hills does not involve any fertilizer nor other significant farming input other than transport, including regular inspections of flocks, it is often suggested that eating meat from these livestock could compete with a vegetarian diet in terms of carbon footprint. Set against this are emissions of CH_4 through enteric fermentation, nitrous oxide (from manure etc) and carbon dioxide (from degradation of peaty soil). APPG (2013) quote data indicating that emissions from upland and lowland cattle and sheep are of a similar order, but with upland beef having lower emissions and upland sheep higher emissions.

Edwards-Jones et al. (2009) report averages of 16.4 kg CO_2(e) per kg dead weight for hill and upland sheep and 15.6 CO_2(e) per kg dead weight for lowland sheep from a Welsh study. However, the paper concludes that there are broad variations for the same product in different farms. Durham University (Worrall and Clay, 2012) found that ewes were responsible for some 90% of total GHG emissions of mutton, with only 10% of the emissions being associated with indirect emissions from sheep trampling peaty soils (Clay and Worrall 2013).

In hill farms, livestock tend to grow more slowly due to being outside all year round, which on average is cooler, which means that they tend to emit more CH_4 for each kg of meat produced. According to Meat Production Wales (2011) animal productivity is dictated by feed quality, feed quantity and animal breed.

Rothamsted Research (2015) suggest soil pH, water balance (rainfall vs evaporation and runoff) and local climate influence N_2O gas production from upland sheep, implying grazing location has a significant impact on N_2O emissions. A study in Southern Australia (Bell et al. 2012) highlights the dependence of N_2O emissions on soil type, climate and pasture species and suggests, based on modelling, that global warming may increase N_2O emissions.

Eating local lamb/mutton vs. a vegetarian diet (in the UK)

It is important to consider possible conflicts between healthy food and food that minimises GHG emissions. In one reported scenario, **Tom et al (2016)** found that in the USA adding a mix of fruits, vegetables, dairy and seafood to one's diet, as recommended by the US government to improve the healthiness of a diet, would result in a 38% increase in production energy use, 10 % increase in water use and an increase in 6% of GHG emissions.

As stated in the earlier sections upland sheep are the largest GHG emitters. However, livestock grazing plays a key role in maintaining species-rich habitats for insects (English Nature, 2005), such as the Hampshire chalk grassland. Without sheep, this habitat would most likely disappear, unless it was maintained by mechanical means, and resulting GHG emissions. Arguably the sheep reduce other emissions, therefore. Sheep and cows are thus an important part of the UK's agricultural and landscape system.

Grains, vegetables and herbs are cultivated in the UK. The arable processes of sowing, establishing, protecting and harvesting the crops require energy, industrial chemicals (pesticides and fertilisers) and water. All these have associated carbon footprints. Furthermore arable processes can result in increased erosion of soil (Boardman et al, 2009) as found in West Sussex. Erosion, particularly of sandy soils, can result in increased GHG emissions (Müller-Nedebock, 2015). Such sandy soils are present in West Sussex, where Boardman et al 2009 highlighted that to eliminate the risk of erosion, it is necessary that arable fields should revert to grassland. Such reversion would not be financially viable without the use of sheep or cattle to maintain the grassland and bring in revenue through sales of livestock. This is why, since 2005, Natural England (formally English Nature) facilitated the funding of arable reversion to grassland to the sum of £1.2 million. This has enabled the enhancement of the farmland environment for wildlife and water quality.

The UK is a net exporter of lamb and mutton (40% exported to the EU in 2014) (Defra, 2016). In the face of Brexit, the fate of the British natural environment could be compromised. A crash in the lamb market would be particularly damaging to Cumbria's economy and environment. This could promote a shift in land use from grassland to arable which, as explained above, may increase GHG emissions and erosion.

It is therefore important to consider an agricultural system as whole. Sheep emit more GHG than cattle, chicken or pigs. However in the UK, consumption of lamb (and beef) makes it possible to maintain habitats and minimise the negative impacts of arable farming.

Benefits of a vegan diet

Eliminating dairy products means that far less livestock needs to be raised, further reducing GHG emissions.

Scarborough et al. (2014) estimate average age and sex adjusted GHG emissions of 2.89 $kgCO_2(e)$ per day for vegans compared with 3.81 for vegetarians, 3.91 for fish eaters and 5.63 for 'medium' meat eaters (between 50 and 99 grams per day). They attribute much of the higher GHG emissions due to animal-based products to the GHG emissions from growing crops for animals to eat and methane emissions from ruminants. Gonzalez et al. (2011) concluded that plant-based protein sources were more efficient than animal-based as far as GHG emissions are concerned.

Poore (2017) estimates that if everyone went vegan this would reduce the amount of arable land required worldwide by between 20% and 40% making more land available for wildlife.

Ready meals vs home cooking

There does not appear to be a lot of research in this area. Rivera et al. (2014) report ready meals have additional manufacturing, refrigeration and waste emissions, while the ready meals with the least impacts are from microwaveable frozen meals prepared with fresh ingredients. Manchester University (n.d.) say a homemade lamb curry incurs 15% less emissions than a similar ready meal.

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