Review

Eating beef: cattle, methane and food production

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A number of prominent people have advocated eating less meat or becoming a vegetarian to reduce global warming, because cattle produce the greenhouse gas methane. This raises a number of questions including: what will happen to the grasslands that much of the world's cattle currently graze; how will alternate protein be produced, and what will the greenhouse consequences of that production be? It comes down to production systems. About 70 per cent of the world's agricultural land is grassland, and the only way to produce food from grasslands is to graze ruminants on it. If domesticated animals do not graze the grasslands, native or feral ruminants, which also produce methane, tend to move in. Feeding high quality grain to cattle is much less defensible. Replacing animal protein with plant proteins like soybeans necessitates more cropping land, water, fuel and chemicals being used. A more rational food system would raise cattle on grasslands but not feed them high quality grains. Instead more of the currently grown crop could be devoted to human consumption.

Key Words: cattle, methane, grassland, grain-fed

VEGETARIANISM AND CLIMATE CHANGE

Eating less meat, or even becoming a vegetarian, has been advocated by individuals arguing for a reduction in anthropogenic greenhouse gas production. They include the Nobel Peace Prize-winner, chair of the United Nations Intergovernmental Panel on Climate Change, Rajendra Pachauri[1] and Britain's former adviser to the government on the economics of climate change, Lord Stern of Brentford.[2]

Lord Stern is quoted as saying "Meat is a wasteful use of water and creates a lot of greenhouse gases. It puts enormous pressure on the world's resources. A vegetarian diet is better." He suggested eating meat "could become as socially unacceptable as drink-driving because of the impact it has on global warming".[3]

But no longer eating meat would have a profound impact on the world's agricultural systems and on food production. About 70 per cent of the world's agricultural land is grassland. The animals raised on grasslands contribute to the livelihoods of 800 million people.[4]

Can we ethically refuse to produce food from so much land in a world where a hungry population is rapidly growing? What will happen to the grasslands if they are no longer grazed by domesticated ruminants? Where will people get the food and nutrition to replace meat in their diets, and what would the greenhouse gas consequences of producing that replacement food be?

GRASSLANDS AND GRAZING: RUMINANTS AND HERBIVORES

The only way grasslands can produce food is through grazing ruminants - cattle, sheep and goats - on them. Most mammals, and that includes humans, cannot digest grass, or more precisely, cellulose. But ruminants possess several compartments in their stomachs. One, the rumen, houses microbes that can digest grass. The problem is that this microbial digestive process also produces the greenhouse gas methane as a by-product.[5]

Methane is a potent, if short-lived greenhouse gas. It is given a global warming potential rating of 25 times that of carbon dioxide over 100 years, though it has a lifetime of 9 to 12 years in the atmosphere.[6]

Grasslands include native pastures and introduced species; it includes the campos of South America, the North American prairie, the Sahelian steppe in Africa, the steppe of south-eastern Europe, Asia and North America and the savannas of Africa, Australia, South America and southern North America.[7]

Grasslands are unsuitable for cropping due to poor soil, low rainfall or topography. Ruminants produce protein from plants in areas that are unsuitable for any other agricultural activity. And before there were modern cattle there were wild ruminants: bison or buffalo, caribou, wildebeest, mouflon, auroch and goats. And they all produce methane.

The great bison herds that swarmed across the US prairies before white settlement, along with other native ruminants like elk and deer, are estimated to have produced 86 per cent of the methane of the current US cattle herd.[8]

When modern day ruminants, cattle and sheep, are removed other ruminants usually move in. In the United Kingdom, that means deer, which are now at record numbers.[9]

When the Maasai tribes and their cattle herds were removed from the Serengeti, to create a national park the

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native ruminants - buffalo, wildebeest, gazelles and giraffe - replaced them. They bred up: wildebeest numbers alone grew from an estimated 250,000 in the early 1960s to around 1.5 million.[10]

Even Australia, which has no native ruminants, now has a large population of ruminant camels, which reached at least one million in 2008 and as many as 2.6 million feral goats.[11,12]

Australia's largest native herbivores are macropods: kangaroos and wallabies. Macropods also have complex stomachs, but their main byproduct of digestion is succinate. There are only a few studies on macropod emissions. The most recent, on red necked wallabies in the Copenhagen zoo, found they produced between 25 and 33 per cent of the methane of a ruminant, per unit of food ingested.[13]

Their low methane emissions plus the fact that kangaroos are soft-footed animals (as opposed to cattle and sheep which have hard hooves which damage Australia's fragile soils and flora), and their meat is low in fat, has lead to a new dietary category in Australia: kangatarians or people who eat kangaroo but not other red meat, on environmental grounds.[14]

The macropod research also provides an interesting line of investigation: could their succinate-producing bacteria be introduced into cattle, and cut their methane emissions? [15]

The Australian naturalist George Seddon argued the main herbivores in Australia were insects, especially termites. He notes Australia has 182 species of termites, while Europe has two.[16] And termites produce methane, three per cent of global methane to be exact. Richard Eckard, who is Associate Professor with the Melbourne School of Land and Environment among other titles, thinks it is quite feasible that termites produce more methane, per area in the Northern Territory, than livestock.[17]

LIVESTOCK AND GREENHOUSE GASES

The amount of methane emitted by cattle is a subject of ongoing debate.

In 2006 the Food and Agriculture Organisation published Livestock's Long shadow, which claimed 18 per cent of global greenhouse gas emissions come from livestock.[18]

The press release announcing the report began: "Which causes more greenhouse gas emissions, rearing cattle or driving cars? Surprise!" According to a new report published by the United Nations Food and Agriculture Organization, the livestock sector generates more greenhouse gas emissions as measured in CO_2 equivalent – 18 percent – than transport. It is also a major source of land and water degradation."

"Says Henning Steinfeld, Chief of FAO's Livestock Information and Policy Branch and senior author of the report: 'Livestock are one of the most significant contributors to today's most serious environmental problems. Urgent action is required to remedy the situation.' "[19]

The report came in for criticism on two main grounds: that it over-estimated the amount of deforestation for livestock production, and that it conducted a full life cycle analysis for livestock, but not for transport.

Richard Eckard argues Livestock's Long Shadow counted all land clearing, despite up to 40 per cent being cropped.[20] In the same article he pointed out that in Australia, (one of the few countries where livestock can outnumber people): "According to the Australian National Greenhouse Gas Inventory, the livestock industries contribute around 11 per cent of national greenhouse gas emissions, mainly as methane and, to a lesser extent, nitrous oxide."

He thinks a global figure of around 12 per cent would be correct.[21]

Dr Eckard argued another incorrect assumption in Livestock's Long shadow, was "it assumes all the livestock in the world are just for human consumption and that is not true. You have all the cattle in India for religious reasons, the cattle in Africa used for transport and wealth generation, a lot do not get consumed."

He argued that attributing all land clearing to cattle production was also incorrect. "In Australia, where the extensive livestock areas are, was never cleared. All the northern rangelands, they weren't cleared. They were just stocked with cattle.

"In the southern areas, a lot of the dairy industry is in areas of high rainfall and cleared of forest to put in pastures. But, by and large, most of the areas, if they were cleared, they were cleared for cropping."

Maurice Pitesky, Kimberly Stackhouse and Frank Mitloehner, in a report on livestock's contribution to climate change, report that in the US work by government agencies, including the Environmental Protection Agency and the California Energy Commission, concluded greenhouse gas emissions associated with direct livestock emissions totalled less than 3% of total anthropogenic greenhouse gas emissions.[22]

The US EPA estimated 7% of 2010 greenhouse gas emissions came from agriculture.[23]

Pitesky et al wrote that one reason for the difference between global and US figures "is due to the significant weight that has been assigned to the category of 'land-use change' patterns related to livestock production (mainly deforestation). Furthermore, LLS attempts a life cycle assessment for global livestock production, but does not use an equally holistic approach for its transportation prediction numbers." [24]

The US EPA stated that in "2010 transportation contributed approximately 27 percent of total U.S. greenhouse gas emissions. Transportation is also the largest end-use source of greenhouse gases (including direct emissions and emissions from electricity use), and accounts for 45 percent of the net increase in total U.S. greenhouse gas emissions from 1990-2010." [25]

Pitesky et al point out that no estimates have been made of what would occur if livestock were eliminated. "The idea that if livestock were simply eliminated, 18% of anthropogenic GHGs would be also be eliminated as well is unrealistic. In fact, many of the resources previously dedicated to domesticated livestock would be utilised by other human activities." [26]

The Intergovernmental Panel on Climate Change, in its 2007 Fourth Assessment Report, states that livestock, "predominantly ruminants such as cattle and sheep" account for about one-third of global anthropogenic emissions of methane. It also states that agriculture, as a

whole, accounted for 12 per cent of total global anthropogenic emissions of greenhouse gases in 2005.[27]

The World Resources Institute estimates livestock and manure are responsible for 5.4 per cent of global emissions. It points out the largest contributor (40%) to agricultural emissions is nitrous oxide from soils (due to "particular tillage and cropping practices, such as fertiliser application"), followed by methane from enteric fermentation from ruminant digestion (27%), methane from rice (10%), energy management (9%) , manure (7%) and other sources (6%).

The report estimates total transportation accounted for 14.3% of World Greenhouse Gas Emissions in 2005.[28]

Methane production, per beast, varies according to a range of factors, including nutrition, genetics and the age at which cows give birth. There can be a 15 per cent difference in methane emissions per animal within the one herd.[29]

A 2010 report - Red meat production in Australia: life cycle assessment and comparison with overseas studies - found the lowest beef carbon footprint came from cattle in a Sahelian pastoral system in Africa, with a carbon footprint of 5.9 to 8.4 carbon dioxide equivalent, per kilo of dressed meat. The carbon footprint for Australian beef ranged between 8.2 and 11.5 CO_2e/kg HSCW [hot standard carcase weight or the carcase after it has been processed at the abattoir].[30]

The paper stated the value for Japan was four times higher than that achieved in the Sahelian pastoral system. Greg Peters from the Sustainability Assessment Program at the University of New South Wales Water Research Centre said the Japanese value of 26 was "probably because they keep their animals in a feedlot for a very long time. They keep them indoors, they probably have environmental controls and fans. It is not just an animal sitting on a hillside contemplating the sunset." [31]

Beef cattle are raised either free-range on grass, or confined in feedlots where they are fed grain. One of the arguments against producing beef hinges on the use of grain that could be used to feed people instead being fed to livestock.

Australian beef cattle spend most of their lives on grass, but many spend 50 to 120 days at the end of their life in feedlots, being fed grain. There they are mostly fed low-grade wheat that is unfit for flour milling, crops grown specifically for livestock like sorghum and oats, and the waste products from making canola and cotton seed oil.[32]

Many environmentalists oppose feedlotting due to its intensive nature and the unnaturally high grain diet.[33] But feedlot cattle grow more quickly than grass-fed cattle, and that means less greenhouse gas. In fact, Australian grain-fed cattle are estimated to produce 38 per cent less greenhouse gas emissions than grass-fed cattle. They grow faster again if they are administered Hormonal Growth Promotants.[34]

Dr Peters explains "we found that surprisingly perhaps, the feedlot animals had a lower carbon footprint than the ones that weren't going through the feedlot system. There is a trade-off here between the extra energy involved in the production of grains harvesting and transporting them to feedlots. There is a carbon footprint associated with all those activities. So on the one hand you have that extra carbon, but with the feedlot there is a benefit because you are feeding the animals much more concentrated food and food that is easier to digest, they put on weight more rapidly per kilo of feed than they would if they were free range." [35]

Research in the UK has found that organic farms are less energy intensive than conventional farming, but they are also less productive. They found organic livestock have higher greenhouse gas emissions per unit of milk or meat. Williams et al in a study for the UK Department of Environment, Food and Rural Affairs, found: "Most organic animal production reduces primary energy use by 15 to 40%, but organic poultry meat and egg production increase energy use by 30% and 15% respectively. The benefits of lower energy needs of organic feeds is overridden by lower bird performance.

"Land use was always higher in organic systems (with lower yields and overheads for fertility building and cover crops) ranging from 65% more for milk and meat to 160% more for potatoes and 200% more for bread wheat." [36]

The UK system relies on feeding grain and harvested roughage to cattle. But in Australia most cattle, and that includes organically-raised cattle, are grazed on pasture. Dr Peter's team found different results in Australia. "We found the organic beef system actually used less energy than the non-organic system, so even though the greenhouse emissions were higher, there were less energy inputs since we don't have grain being brought into the feed lot, which is a key part of the non-organic system we looked at, and we don't have all transportations burdens." [37]

The former Chief of CSIRO Livestock Industries, Alan Bell estimates beef cattle account for up to seven per cent of Australia's greenhouse gas emissions. And that figure is set to fall. The current estimate is based on old data that have recently been found to overstate the methane produced by northern cattle by 20 to 30 per cent. With about half the nation's cattle in the north, this means a significant downward revision.[38]

EFFICIENCIES AND ENVIRONMENTAL FOOTPRINTS

Both beef and dairy cattle have become more much efficient: as production per animal increases, the carbon footprint per kilo of steak or litre of milk decreases.[39]

Dr Bell observed: "If we keep pushing for less methane per unit of meat or milk, then we have a yardstick to measure ourselves by. It is true that Australian beef in those terms has become not only more productive in the normal output to input ratio, but also more efficient in terms of less greenhouse gases per amount of beef produced. Then you bring in factors like the rate of turnoff of your young cattle, reproductive efficiency, anything that make the system more efficient will end up being beneficial, both in terms of productivity and also in terms of environmental performance." [40]

Bell cites work by a student in his former department at Cornell University, Judith Capper. She estimated that in 2007, US dairy cows produced just 37 per cent of their 1944 greenhouse gas emissions per unit of milk, a figure in line with their dramatic increase in milk productivity.[41]

Dr Capper, in a speech titled 'An Overview of the Environmental Impact of Beef and Dairy Systems' in July 2011 stated US beef and dairy systems "have considerably reduced resource use and carbon emissions over time. Advances in nutrition, genetics and management allowed dairy cow productivity to increase four-fold between 1944 and 2007, with 21% of the animals, 23% of the feed, 35% of the water and 10% of the land required to produce one kg of milk in 2007 compared to 1944."

She argued these increases lead to a 19% reduction in feedstuff, a 14% reduction in water use, 34% reduction in land use "and the carbon footprint was 18% lower per kg of beef in 2007". She suggests further gains could be made in the beef industry. "Indeed, growth-enhancing technology use within conventional beef production reduced land use by 45% and carbon emissions by 42% per kg of beef compared to grass-finished systems. To improve future environmental sustainability it is crucial to maintain access to management practices and technologies that improve productivity." [42]

In 2010 the world cattle population was estimated at 1,010 million, down from 1,025 million in 2007.[43]

According to the 2009 FAO report 'The State of Food and Agriculture', global production of beef rose from 54,191,000 tonnes in 1995 to 61,881,000 tonnes in 2007. World-wide, protein from all forms of livestock provided 11.8 per cent of calories and 25.8 per cent of protein in 1995, and 12.9 per cent of calories and 27.9 per cent of protein in 2007. Those in developed countries consumed a much greater share of calories and protein from livestock (20.3% and 47.8% respectively in 2005) than those in developing countries.[44]

LIVESTOCK, FOOD SECURITY AND LIVELIHOODS

The FAO report states that livestock contribute 40 per cent of the global value of agricultural output and support the livelihoods and food security of almost one billion people. It states: "Consumption of livestock products has increased rapidly in developing countries over the past decades, particularly from the 1980s....Since the early 1960s, consumption of milk per capita in the developing countries has almost doubled, meat consumption more than tripled and egg consumption has increased by a factor of five".[45]

CARBON SEQUESTRATION

Grasslands have another important role to play: sequestering, or fixing, carbon. The Australian government-funded scientific research body, the CSIRO, has estimated that 164 million tonnes of greenhouse gases could be stored each year through agricultural activities like rehabilitating grasslands, restoring soil and vegetation carbon, and reducing savannah (northern grassland) burning.[46]

In 2011, Australia emitted an estimated 544.3 million tonnes of greenhouse gases.[47]

Grasslands fix carbon as they grow; but they have evolved to be eaten. If they were no longer grazed the grasses would grow rank and stop fixing carbon. And, in Australia, they would in all likelihood burn.[48]

Bushfires, on average, burn over 500,000 square kilometres of Australia annually, mainly in the grasslands in the northern half of the country. Bushfire accounts for about three per cent of the nation's net greenhouse gas emissions.[49]

Increasing soil organic carbon levels is seen as one way of increasing Australia's carbon sequestration. The conversion of native plants to agriculture has typically resulted in losses of between 40 and 60% of carbon compared with pre-clearing levels. Improved management of crop land has resulted in small increases in soil carbon, mostly occurring in the first ten years. However the data show larger gains in improved management of pasture which includes green manuring and shifting from annual to permanent pastures. A report, Soil Carbon Sequestration Potential: A review for Australian Agriculture prepared for the Australian Department of Climate Change and Energy, written by Jonathon Sanderman, Ryan Farquharson and Jeffrey Baldock from CSIRO Land and Water, stated: "Perhaps the greatest gains can be expected from more radical management shifts, such as conversion from cropping to permanent pasture and retirement and restoration of degraded land".[50]

RUMINANT VERSUS MONOGASTRIC LIVESTOCK

So should we keep farming, and eating, meat? This is a question currently being asked in the UK, prompted in part by rural journalist and farmer Simon Fairlie's book, 'Meat a Benign Extravagance'. At the risk of simplifying a very complex argument, Fairlie essentially argues the case for the return to meat being produced from grazing by ruminants, and feeding crop and food waste to monogastrics such as pigs and chickens.

Fairlie is particularly critical of the practice of feeding high-quality grain to ruminants which are the animals least able to process it efficiently. "Cattle are excellent converters of grass but terrible converters of concentrated feed. The feed would have been much better used to make pork." [51]

Fairlie's book famously persuaded well-known environment writer George Monbiot that his pro-vegan stance was wrong. Under the title 'I was wrong about veganism. Let them eat meat – but farm it properly', Monbiot recanted. He concluded: "The meat-producing system Fairlie advocates differs sharply from the one now practised in the rich world: low energy, low waste, just, diverse, small-scale. But if we were to adopt it, we could eat meat, milk and eggs (albeit much less) with a clean conscience." [52]

Cattle are not good converters of grain to protein, requiring 7 to 10 kilos of grain to produce one kilogram of meat. Pigs require 3 kg of feed and chicken requires just 1.7 kilos of grain to produce one kilo of meat.[53-55]

Pigs and chickens are monogastric omnivores: they have one stomach and can eat and digest grains and animal protein. Traditionally both were largely fed on farm and household waste, but increasing urbanisation and the industrialisation of pig and poultry farming has lead to both being fed rations largely comprising high-quality grains.[56]

According to the Climate Change Report, produced for the Australian Government by Ross Garnaut, for every kilogram of beef 24 kilograms of carbon dioxide equiva-

lent is produced. Lamb produces 16.8 kg. The figure for pork is 4.1 kg of carbon dioxide equivalent per kilo of meat, and for chicken it is just 0.8 kilos of CO_2 e.[57]

Bell points out that some grains are grown specifically for livestock and are not consumed by humans. These include sorghum, feed barley and feed grade wheat in Australia and so called 'cow corn' in the US.

"People say ruminants produce methane and are less efficient than pigs and poultry, but think about all that grain that we need to produce protein from pigs and poultry," Bell says. "If you just assess the efficiency of ruminants in terms of energy, they always come out worse because of their inefficient digestive systems, but if you use a ratio of human edible output to human inedible input, then ruminants come out often superior." [58]

Brad Ridoutt from the CSIRO's Sustainable Agriculture Flagship has been researching water and carbon footprints of a number of agricultural products. "The first point is there is no simple quick fix solution, such as stop eating meat, because it is a complex system. There are consequences and knock on effects." He cites the example of the push to "a more industrial meat-production system, based on chicken and pigs. Traditionally a lot of these animals were raised on waste. Now to make the productivity very high, very nutritious diets are being fed to them, so the land base that is supporting those forms of meat production is very much in conflict with the land base we might be using to produce cereals we might directly consume. You push in one direction, often it pushes out somewhere else." [59]

GRAIN AND OILSEEDS AS LIVESTOCK FEED

In 2008 the price of grain doubled. Aid agencies were unable to purchase all the grain they needed. Some countries placed embargoes on grain exports, and there were food riots in half a dozen countries. Grain production had fallen short due to a range of adverse climate events, as demand had been rising. As people's standard of living rises, they switch from grain-based diets to eating more animal-derived protein, and that was the case across China, Indonesia and other Asian countries.

But there were two other factors at play. Critics condemned the use of grain for fuel, and questioned the large quantities of grain being fed to livestock, rather than people.[60]

Australia is one of the world's top grain exporters. But an increasing percentage of the Australian grain crop is being used domestically to feed livestock - mainly cattle, pigs and poultry. Of these products, only cattle, as live cattle or beef, is exported in quantity.

Some feed grains, like sorghum, triticale, some grades of barley and oats and corn, are grown exclusively for livestock, though it could be argued they replace crops grown for human consumption. Other grains are multi purpose, for example wheat that is downgraded and not fit for human consumption is used for stock feed.

In Australia, the percentage of the grain crop fed to livestock is growing. The GRDC reports: "The poultry industry began to grow strongly in the 1960's based on grain feeding. Dairy production was at that time almost entirely grass based, and cattle lot feeding in Australia has only become a key part of the beef industry over the past 20 years."

Between 1993 and 2007 feed grain demand by domestic livestock industries grew from 5.7 million tonnes to around 9 million tonnes. The 2008 GRDC feedgrains report indicated that if recent growth in feedgrain demand continued, by 2015 about 58 per cent of all cereal grain in Australia will be used for livestock feeding.[61]

In 2003/4, 2.18 million tonnes of the 26.13 Mt wheat crop (8%) was used for stock feed, while 17.9 Mt were exported. For coarse grain crops (barley, oats, triticale, sorghum and maize) 6.6 Mt, or 40% of the 15.63 Mt crop was used for stock feed, and 7.8 Mt exported.[62]

By 2011/12, 3.5 Mt of the record 29.5 Mt wheat crop (12%) was used for stock feed and 22.3 Mt tonnes was exported. Of the 13.6 Mt coarse grain crop, 6.7 Mt or 49 per cent was used for feed grain, and 6.7 Mt exported. [63]

Grain analyst John Spragg estimates that between 1993/94 and 2010/11, feed grain use by Australian livestock jumped by 60%, or an average annual growth of 3.6% over the 17 year period. He noted the 2010/11 figure came at the end of a long dry period, and was below the high of 2006/07 when beef feedlots were at full capacity.

Of the feed used by the Australian livestock industry in 2010/11, Spragg estimated 23 per cent went to the dairy industry, 21% to beef feedlots, 21% to the poultry meat industry, 16% to the pig industry, 7% to laying hens, with the remainder going to grazing animals (as supplementary feed), horses and sheep.[64]

Australia's government forecasting body, ABARES estimated the 2011/2012 world wheat production total production would reach 695 million tonnes (though at the time of writing, August 2012, it remained to be seen what influence drought in the US would have on this figure). Assuming it reaches 695 million tonnes, ABARES expects 142 Mt of wheat to be used for feed. An additional 1,141 Mt of coarse grains is forecast, much of which will be used for livestock.

The Australian production forecast is 50 Mt of grains and oilseeds (including 29.5 Mt of wheat). Of this, 32.8 Mt are expected to be exported.[65]

Should an increasing percentage of grain crops be fed to livestock, and specifically to cattle? Should cattle be put out to pasture, rather than fed grain, and are there alternatives for livestock with a higher protein demand, like pigs and poultry?

Tara Garnett, from the UK's Food Climate Research Network, believes that although poultry and pigs are more efficient converters of plant energy than cattle and produce less greenhouse gas, they do have an environmental problem: they are more dependent on grains. She argues we should take what she calls an "ecological leftovers" approach. Rather than feeding livestock good quality grain, we should be feeding them byproducts like molasses cake, brewers grains, vegetable residues and rice husks.[66]

In Australia, household food waste alone amounts to four million tonnes a year, while Britons are estimated to throw out between 18 and 20 million tonnes of food per annum.[67,68]

Fairlie also makes the case for returning to feeding of food waste to pigs. He estimates that in the UK, waste

food could be used to produce one sixth of their total meat consumption. But in the UK feeding food waste to pigs was banned in 2001, after the catastrophic outbreak of foot and mouth disease.

Until the early 1990s, only one third of pig feed in the UK consisted of grains that were fit for human consumption: the rest was made up of crop residues and food waste. Since then the proportion of sound grain in pig feed has doubled. Fairlie says there are several reasons for this: the rules set by supermarkets and the domination of the feed industry by large corporations which can't handle waste from many different sources. But the most important is the ban on food waste that came in after the BSE or mad cow, and foot and mouth crises.

The UK pork industry halved between 1998 and 2007. Britons still eat the same amount of pork, only now much of it is imported.[69]

If a person decides not to eat meat, what do they turn to for protein, and what environmental impact will that substitute have?

Consumers in the United Kingdom are starting to ask questions about where their non-meat protein comes from, and what environmental costs are being incurred. A study by Cranfield University, commissioned by the environmental group WWF, reported that many meat substitutes are produced from soy, chickpeas and lentils, but these crops can't be grown in Britain. The report found a switch to these substitutes would result in more foreign land being cultivated, and raise the risk of forests being destroyed to create farmland. It also found meat substitutes tended to be highly processed and involved energy-intensive production methods.

One of the study's authors, Donal Murphy-Bokern, said: "For some people, tofu and other meat substitutes symbolise environmental friendliness but they are not necessarily the badge of merit people claim."[70]

ARABLE LAND AND WATER

While the UK imports its soybeans from cleared Amazon forest, Australia at least grew about 14 per cent of the soybeans it consumed last year. But a major limiting factor in Australia is irrigation water: under Australian conditions soybeans need between 4.5 to 8.5 million litres per hectare, with an average around 6.5 ML/ha. This compares with cotton's 6.3 million litres.[71,72]

Soybeans, lentils and chickpeas also need cleared land, something else that has a finite supply. This is a particular problem in Australia where soil types, restrictions on land clearing and competition with the mining industry all limit supply of land.

There will be less irrigation water in the major irrigation area of Australia, the Murray-Darling basin. The Murray-Darling river system is Australia's most important river system, covering 1,061,469 square kilometres or 14% of the country. It is referred to as the nation's food basket, producing over one third of the country's food. But too much water has been taken from the Murray-Darling, and the Federal and Murray-Darling State governments are currently engaged in a long process of returning irrigation water to the river system. At the time of writing, they were considering reducing the amount of water that could be taken for irrigation by 2,750 gigalitres or billion litres. The current legal diversion limit is 13,700 GL/year of surface or river water, and 1,700 GL/year of ground water.[73]

FOSSIL FUELS, FERTILISERS AND PESTICIDES

Crops also rely on the petrochemical industry. When horses and oxen were replaced by diesel-powered tractors, agriculture shifted from relying on energy from the sun, captured by plants and fed to livestock, to reliance on greenhouse-gas producing fossil fuels.

This has lead to the expression Eating Fossil Fuels, popularised by the writer Dale Allen Pfeiffer in his book of the same name.[74]

The production of fertilisers and herbicides, used in crop growing, also results in significant greenhouse gas production. In particular, crops need nitrogen, and most comes from synthetic nitrogen fertiliser. Distinguished professor in Environment at the University of Manitoba, Vaclav Smil, argues the Haber-Bosch process, which produces synthetic nitrogenous fertiliser, has underpinned the dramatic increase in food production during the last century, and thus in the increased world population. "Synthetic nitrogenous fertilisers now provide just over half of the nutrient received by the world's crops," Smil writes. "Without the use of nitrogen fertilisers we could not secure enough food for the prevailing diets of nearly 45% of the world's population, or roughly three billion people".[75]

But making nitrogen fertiliser comes at a very large cost: it is a very energy intensive process, using at least four per cent of the world's energy supply.[76]

Nitrogen fertilisers breaks down in agriculture to become the potent greenhouse gas nitrous oxide which has a global warming potential of 298.

ORGANIC FARMING AND COOKING

Organic farms fix nitrogen through growing legume crops. And this contributes to their lower productivity, with essentially one third of fields taken out of grain production, on a stockless farm, for natural nitrogen fixing.[77]

Most legumes need to be processed, or at least cooked for some time, to be edible, and if that cooking process uses coal-fired electricity or gas that means more greenhouse gas production.

IN CONCLUSION

Tara Garnett points out: "it is, of course, the case that if people did not consume livestock products, fewer cereals would be required for livestock, but more for direct human consumption. It is possible then that a reduction in livestock consumption might lead to an increase in the land area required to grow cereals, perhaps leading to additional land use change derived CO_2 emissions."

She argues that a reduction in the consumption of meat and milk in developed countries would "be in keeping with principle of global equity".[78]

Garnett said her "ecological leftovers" approach "takes ecological capacity as the ultimate constraint; using land for livestock that is genuinely unsuited to other purposes." She said this would lead to genuine greenhouse gas benefits, "since it maximises livestock's carbon sequestering and resource efficiency functions and minimises

the negative impacts from intensive livestock. This is a radical scenario - but in the absence of additional planets to support the lifestyles we want, it may be the only viable option," she said.[79]

AUTHOR DISCLOSURE

The author has no conflict of interest.

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Review

Eating beef: cattle, methane and food production

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吃牛肉：畜牛、甲烷及糧食生產

因為畜牛會產生溫室效應的甲烷氣體，故一些名人提倡少吃肉或是成為素食者，以減少全球暖化。這牽涉幾個問題包含：世界上許多原先放牧畜牛的那些草原會變成如何；替代蛋白質如何被生產以及那個產物的溫室結果將會是什麼?這歸結到生產系統。世界上的農地有 70%是草原，從草原生產糧食只有一個方法，就是放牧反芻類動物。假如沒有在草原放牧家畜，原生或是野生反芻類動物會遷移進去，也產生甲烷。餵食畜牛高品質穀類的做法是更難站得住腳的。以植物性蛋白替代動物性蛋白，例如大豆，需要使用較多耕地、水、燃料及化學物質。一個較合理的糧食系統應該是將牛群放養在草原上，而不餵食牠們高品質穀物。這樣反而有更多現行的作物可提供人類食用。

關鍵字：畜牛、甲烷、草原、穀物餵養