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Review

Production of Meat and Milk from Grass in the United Kingdom

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Abstract: Grassland accounts for a high proportion of the agricultural area of the United Kingdom, but the significance of its contribution to the nation's food supply has been questioned. Using representative figures for the composition of UK ruminant livestock diets, we estimated the total production of human-edible protein from grass and forage crops consumed by cattle and sheep. We found that this equates to 21.5 g of protein per person per day, of which 15.2 g comes from milk, 4.71 g from beef and 1.60 g from sheep meat. This represents 45% of the total amount of human-edible animal protein produced in the UK (46.6 g/head) and is equivalent to one-third of the recommended adult human daily protein intake of 64 g/head. Given the growing pressure to produce food in a more resource-efficient manner, grasslands have a valuable role to play in providing food alongside multiple public goods.

Keywords: grassland; protein; cattle; sheep; food system sustainability; resource efficiency; sustainable diets

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1. Introduction

Livestock farmed in the UK make a substantial contribution to the nutrition of the nation, but concerns around the significant environmental impacts associated with their production have fuelled a debate about dietary change and how best to improve the sector's sustainability. Efforts to limit the global temperature rise to below 1.5 degrees C by 2050 are intensifying [1], and a large number of studies have identified the high carbon footprint of meat generally, and beef and lamb in particular, as a major concern [2–5]. In contrast, poultry meat has frequently been associated with lower health and environmental impacts than beef and lamb, including those related to cancer, heart disease, biodiversity loss, land and water use and eutrophication [3,6,7].

In response to these issues, there have been calls for a major reduction in ruminant numbers and beef, lamb and dairy consumption, alongside a further shift towards monogastric and more intensive ruminant livestock production systems [2,8–10]. In the UK, the Climate Change Committee has recommended a minimum reduction in the average amount of beef, lamb and dairy consumed per person of 'at least 20%', which they estimate will equate to a 10% reduction in cattle and sheep numbers, if expected population growth is taken into account [11].

However, with demand for beef, lamb and dairy rising globally [12], there is a strong case for favouring those ruminant production systems with the greatest sustainability credentials. Identifying these systems requires taking account of the major differences in the environmental footprints of ruminant products depending on the method and region of their production [3,13].

Another major though often overlooked consideration is the issue of 'food-feed competition', the series of trade-offs that occur when livestock are reared on crops that could instead be fed to humans [14]. Livestock given large quantities of human-edible feeds, such as cereal grains and soyabean meal, tend to be highly productive due to the superior energy and protein concentrations of these feeds compared to forages. Approximately 40% of the world's arable land is used to produce livestock feed [15], while farm animals consume one-third of total global cereal production [14].

Even the most productive grain-fed livestock are, nevertheless, inefficient at converting edible crops into meat, milk and egg protein, and this results in a net loss of calories and nutrients. For instance, at the global level, pigs and poultry given diets which contain high proportions of potentially human-edible feed produce, on average, only 240 g of protein as meat and eggs for every kilogram of human-edible protein consumed [15]. Such dependence on grain also comes with a range of negative impacts including the degradation of arable soils with associated losses of organic matter, carbon and structure. In contrast, livestock fed on grass and other human inedible feeds are positive contributors to human food supply as they produce nutrient-dense food from materials which humans would otherwise be unable or unwilling to eat [15]. Only 7% of UK grasslands are degraded, compared with 38% of UK arable soils [16]. In addition, Van Zanten et al., 2018, show that human diets containing no animal-sourced foods require more arable land than those that utilise products from low-cost livestock systems [17]. However, while a number of studies have modelled the potential contributions of grass and grazing livestock to the global protein supply [17–19], there are few hard data on their current contribution [20].

Grassland and rough grazing currently comprise approximately 67% of the UK's agricultural area. Of this, 33% is permanent pasture, 6.4% is common land, 6.3% is temporary grassland and 21% is rough grazing [21]. Although a proportion of UK grassland is suitable for conversion to arable cropping, this would release very substantial amounts of carbon dioxide and nitrous oxide [22]. Furthermore, a high proportion of UK farmland is unsuited to arable crop production due to topography, soil type, local climate and other factors.

The food production value of grazing land has been questioned [23,24]. In addition, the Climate Change Committee has recommended that up to 32% of the UK's grassland area should be removed from ruminant production by 2035 [25]. However, as a consequence of such a change, there is a risk that the UK could increase the overall carbon footprint of food consumption by importing more beef and lamb to replace lost home production [11]. We therefore attempted to estimate the significance of the UK's grasslands and forage crops in terms of protein production from livestock, as a guide to the extent to which future supplies of home-fed milk and meat might be affected.

2. Home-Fed Production of Livestock Products

Home-fed (i.e., domestically reared) livestock currently provide the majority of animal food products consumed in the UK. In 2018, home-fed production equated to 80% of the UK's total new supply (home-fed production plus imports, less exports) of beef and veal, 62% of pig meat, 100% of sheep meat, 89% of poultry meat, 106% of milk and 89% of eggs [21].

Changes in home-fed production over the past decade, along with relevant human-edible proportions and crude protein proportions of total animal product, are shown in Table 1. With the exception of sheep meat, home-fed production increased in all livestock sectors between 2008 and 2018, from 17.2 to 19.6 million tonnes fresh weight per year—an increase of 13.8% in this period. The UK population also increased during this period, from 61.8 million in 2007–2009 to 66.5 million in 2017–2019—an increase of 7.5% [26].

Table 1. Home-fed UK production of livestock products, human-edible and crude protein proportions.

	Home-Fed Production ('000 Tonnes Per Year)			Edible Proportion of Total Product [e]	Crude Protein Proportion of Edible Product [f]
	Average 2007–2009 [c]	Average 2017–2019 [d]	Change (%)		
Beef and veal [a,b]	859	907	5.63	0.75	0.21
Sheep meat [a,b]	325	308	−5.03	0.70	0.20
Milk	13,362	14,933	11.80	1.00	0.03
Pig meat [a,b]	698	893	28.00	0.65	0.20
Poultry meat [a,b]	1463	1893	29.40	0.75	0.19
Eggs	489	632	29.10	0.90	0.13

[a] Includes meat produced from cull breeding animals as well as those reared for meat. Does not include offal. [b] Carcase weight. [c] Data taken from [27]. [d] Data taken from [21]. [e] Excluding bones, fat and eggshell, data taken from [28–30]. [f] Figures for beef and veal, sheep meat, pig meat and poultry meat from FAO [31]; figures for milk and eggs from Public Heath England [32].

3. Edible Animal Protein Production

Crude protein (CP) is a useful metric for comparison between foods sourced from different animal species and when comparing nutrient supply with daily human requirements, since protein from animal sources contains the full range of essential amino acids required for an adult diet [33].

The estimated UK home-fed production of edible animal protein in 2008 and 2018 is shown in Table 2. Production per year was converted to grams per capita per day by dividing by 365 days and then by the total UK population. Between 2008 and 2018, production per capita increased, with the exception of sheep meat.

Table 2. Estimated UK home-fed production of edible animal protein (excluding fish), 2008 and 2018.

	Animal Protein Production			
	'000 Tonnes/Year		Per Capita, g/day [c]	
	Average 2007–2009 [a]	Average 2017–2019 [b]	Average 2007–2009	Average 2017–2019
Beef and veal	135	143	5.98	5.89
Sheep meat	45.50	43.12	2.02	1.78
Milk	441	493	19.50	20.30
Pig meat	92	117	4.08	4.82
Poultry meat	210	271	9.29	11.20
Eggs	55.90	72.20	2.48	2.98
Total	979.40	1139.32	43.35	46.97

[a] Data taken from Table 1. [b] Data taken from Table 1.[c] See text for conversion from production per year to per capita per day.

4. Edible Animal Protein Production from Grass and Forage Crops

Grass is the predominant feed given to cattle and sheep in the UK. Relatively few herds and flocks are kept entirely on grazed and conserved pasture; just 10,000 hectares of UK grassland was managed to Pasture for Life standards (i.e., 100% grass-fed) in 2015 [34], although the area is understood to be increasing. A mix of cereal grains and by-products from the human food, drink and bio-energy industries is also included in diets, mainly during the winter months. There is, of course, considerable farm-to-farm variation in the quantity and proportion of different feeds used for each species.

The relative proportions of grazed pasture and conserved grass in the total diet of UK ruminants are difficult to estimate due to variation in the systems of production between different regions. We therefore used typical proportions of grass and forage crops in diets for cattle and sheep (Table 3) to estimate meat and milk output from grass, according to the proportion of total dry matter intake that comes from forage. These proportions are taken from Wilkinson, 2011 [35], which describes some representative UK livestock production systems, the data for which were taken from life cycle assessment modelling of the UK livestock sector [36]. The grass and forage proportions we list in Table 3 are averages of the values listed in Wilkinson, 2011 [35]. Grazed pasture accounts for most of this proportion (69% of total forage dry matter intake), with grass silage accounting for 22%, hay 5%, and maize silage only 4% [35].

Table 3. Estimated UK home-fed beef, sheep meat and milk produced from grass and forage crops, 2018.

	Total Production			Grass and Forage Crops in Typical Diet	Produced from Grass and Forage Crops		
	Fresh Weight Per Year ('000 Tonnes) [a] (A)	**Protein Per Year ('000 Tonnes) [b] (B)**	**Protein Per Capita (g/day) [b] (C)**	**Proportion of Total DM [c] (D)**	**Fresh Weight Per Year ('000 Tonnes) (A × D)**	**Protein Per Year ('000 Tonnes) (B × D)**	**Protein Per Capita (g/day) [d] (C × D)**
Beef	907	143	5.89	0.80 (0.70)	726 (635)	114.40 (100.10)	4.71 (4.12)
Sheep meat	308	43.12	1.78	0.90 (0.80)	278 (246)	38.79 (34.48)	1.60 (1.42)
Milk	14,933	493	20.30	0.75 (0.65)	11,200 (9706)	369.80 (320.50)	15.20 (13.20)
Total	16,148	679.12	27.97		12,204 (10,587)	522.99 (455.08)	21.51 (18.74)

[a] From Table 1. [b] From Table 2. [c] From Wilkinson, 2011 [35]. Parenthesised values assume that the proportion of grass in cattle and sheep diets is 10% lower than in the systems described in Wilkinson, 2011 [35]. [d] See text for conversion from production per year to per capita per day.

On this basis, we estimate that 12.204 million tonnes (fresh weight) of milk, beef and sheep meat was produced from grass and other forage crops in the UK, equivalent to 21.7 g of edible animal protein from grass per capita per day in 2018. Meat and milk derived from grass therefore accounted for approximately 45% of total UK edible animal protein production.

While the example production systems used here are typical of the UK, it is difficult to know how fully representative they are of the sector as a whole. Furthermore, the significant increase in milk yields between 2011 [27] and the present day [21] suggests that ruminant diets, at least within the dairy herd, could have changed since Wilkinson, 2011 [35]. For these reasons, we produced additional estimates of meat and milk output from grass, assuming a 10% lower proportion of grass in ruminant diets than outlined in Wilkinson, 2011 [35], to explore what the contribution of grasslands might be using more conservative assumptions. Using these alternative figures, parenthesised in Table 3, we estimate that 10.587 million tonnes fresh weight of milk, beef and sheep meat was produced from grass and other forage crops in the UK, equivalent to 18.74 g of edible animal protein from grass per capita per day in 2018—which, at approximately 40% of total UK animal protein production, would still represent a very significant contribution to the protein supply.

It is worth noting that wild game, farmed deer and free-range pigs and poultry also obtain all or some of their feed from grass and other forages. However, due to a lack of data, we have not attempted to estimate the contribution of these to the human protein supply.

5. Edible Animal Protein Consumption by the Human Population

To help evaluate the significance of protein produced from UK grasslands to the human protein supply, we compared our findings with the recommended and average daily intakes of protein. According to the National Diet and Nutrition Survey (NDNS) [37], the total daily protein intake by UK adults between 19 and 64 years of age averaged 76 g per capita between 2016 and 2019. This is above the average daily requirement for adults of 64 g/day, which is based on a reference intake value of 0.83 g/kg of bodyweight per day [20]. The total animal protein intake per capita is estimated, on average, to be 39.6 g/day, comprising 25.9 g/day from meat and meat products, 9.9 g/day from milk and milk products and 3.8 g/day from eggs and egg dishes (Table 4).

Table 4. Average intake of livestock protein and amount available for consumption per capita in UK, 2018.

	Average Livestock Protein Intake Per Capita, 2016–2019 (g/day) [a]	Amount of Livestock Protein Available for Consumption Per Capita, 2017–2019 (g/day) [b]
Beef	4.6	7.2
Sheep meat	1.5	1.7
Milk	9.9	19
Pig meat	3.8	7.6
Poultry meat	12.2	12.3
Eggs	3.8	3.4
Other processed meats	3.8	No comparable data
Total	39.6	51.2

[a] Public Health England [37]. [b] Defra [21].

Table 4 also shows the amount of livestock protein available for human consumption, calculated from Defra's 'new supply' data [21]. Note that Table 4 compares slightly different time periods because the NDNS data are averaged over four years between 2016 and 2019, unlike the three-year period we have used elsewhere in this paper. While this discrepancy may have some bearing on the clear differences between the two sets of figures, it is unlikely to be significant. It is also worth noting that these figures are averaged across the whole of the UK population, and do not account for the 2–3% of the UK population who are estimated to be vegan, and the 5–7% who are estimated to be vegetarian [38]. If these groups were removed from the calculations, then the numbers in Table 4 would be slightly higher.

The values for average protein intakes [37] and amounts available for consumption [21] per capita (Table 4) are similar for poultry meat, lamb and eggs, but differ significantly for beef, milk and pig meat, with the NDNS data indicating much lower levels of consumption of these foods than the Defra data would suggest. An under-reporting of consumption in the NDNS data is likely to explain part of this difference [20], as is the 'loss' of protein which occurs when milk is processed into dairy products (at present, over 50% of the total UK new supply of milk is used for the manufacture of cheese and other dairy products [21], though most of the protein 'lost' as whey during the manufacture of cheese is fed to pigs, and so still ends up in the food chain). The discrepancy between the NDNS and Defra totals for beef and pig meat may also be partly explained by some of these meats being categorised as other processed meats (which includes burgers, kebabs, sausages, meat pies and other meat products within the NDNS data). Finally, post-farmgate losses and waste are not accounted in the Defra figures.

6. Ability of Extensive Grass-Based Production to Upgrade Low into High Quality Protein

An additional consideration not included in our calculations is protein quality. Different sources of protein vary considerably in their nutritional value, with animal-sourced foods generally being the most complete due to their desirable balance of essential amino acids and high digestibility. For this reason, the FAO recommends that protein quality, and not just total protein intake, be included when formulating dietary guidelines [39].

Protein quality has also recently been recognised as an important issue when measuring the efficiency of livestock at converting protein in animal feed into protein in meat and milk. In a comparison of four Swedish production systems, both intensive and extensive, all of which included some grain in the diet, extensive, pasture-based systems were found to upgrade both the quantity and quality of human-edible protein, while the system with the greatest reliance on grain failed to do so [40]. In a study of protein conversion efficiency in Austrian dairy farms, milk protein was found to have a digestible indispensable amino acid score 1.87 times higher than that of the human-edible protein in the cattle feed, which, when factored into the study's calculations, resulted in a higher protein conversion efficiency than would have been the case had quality not been considered [41].

The relevance of protein quality to public health, feed conversion efficiency, or any other variable being considered depends in part upon the wider dietary context. Where essential amino acid intake is already sufficient, or in excess of requirements (as is largely the case in developed countries), then protein quality becomes a less relevant consideration; indeed, it may be that a reduction in animal-sourced food consumption would be beneficial for human health in these instances [6]. However, in diets with a limited intake of animal-sourced foods, and where deficiencies in certain essential amino acids are more likely (for instance, in parts of the developing world [42]), then protein quality becomes a very significant factor [43]. Higher-quality proteins could also allow for essential amino acid requirements to be met from a lower consumption of calories [41]. Accounting for protein quality is therefore an important consideration when assessing the contribution of livestock systems to food supplies and public health [44]. Finally, it is important to note that a consideration of the full range of nutrients important for human health (and not just protein) is vital when assessing the nutritional significance of different sources of food.

7. Potential Implications of Changes in Meat Consumption Patterns

The calculations in this paper show that, through the production of meat and milk, grasslands are a significant source of human food in the UK. Given the growing pressure on the world's croplands and increasing concerns around the feeding of livestock on human-edible crops, the contribution of grassland to human food production may be of relevance from a food security perspective.

The challenge is to maximise the contribution to the human food supply of grasslands and forage crops through better utilisation of pastures, whilst minimising the use of human-edible feeds such as cereals. Returning livestock to their traditional role as 'upcyclers' of feeds which humans cannot eat would result in a major decline in the overall availability of animal foods in the developed world. However, this would still represent a highly significant contribution to human nutrition; a global meta-analysis indicates that if livestock were to be reared solely on inedible feeds, they would be able to provide the world with between 9 and 23 g of protein per person per day, as well as 20% of total calcium and zinc requirements and 75% of vitamin B12 requirements [17]. While this would require a major change in diets, achieving this would result in a livestock sector whose contribution to the human food supply would be more resource efficient, freeing up a significant area of arable land for the production of human food crops, and requiring less arable land than would be required under a global transition to plant-based diets [17].

Taking this 'low cost' or 'default' approach to livestock production [17] is also likely to lend itself to the delivery of other benefits that extensive, pasture-based systems can provide, but which risk being lost by a move to more intensive methods of production. For instance, many beef, sheep and dairy farms in the UK are located in regions that are unsuited to other forms of agriculture, and grazing livestock therefore play a valuable social and economic role in disadvantaged rural areas [45]—a service that is of even greater importance in parts of the developing world [46]. Although extensive ruminant production is a major cause of habitat loss in areas of the globe where production is increasing [47], and overstocking and poor grazing practices can have negative effects on biodiversity in the UK, well-managed grazing is also important for many habitats and species of wildlife [48], while the cultural landscapes shaped by livestock activity are widely cherished for their scenic value [49]. Animal welfare standards are also generally perceived to be the highest in extensive grazing livestock systems, particularly when it comes to the provision of an animal's behavioural needs [50]. Furthermore, with huge increases in the price of fertilisers since 2021 and issues around pesticide resistance [51,52], arable farmers are increasingly recognising the key role of temporary grassland and grazing livestock in rotational cropping systems, through their positive impact on soil health, in generating fertility and in controlling persistent weeds [53,54].

Perhaps the main criticism of rearing livestock in grass-based systems of production is that it tends to result in higher carbon footprints per unit of food than do intensively produced livestock products [3]. However, when nutrient density is used as the functional unit instead of product mass, the carbon footprint of beef (though not lamb) has been found to be similar to that of pig and poultry meat, due to the superior nutrient profile of beef [55]. In addition, studies suggest that, under a transition towards more agroecological farming practices, a predominantly extensive, pasture-based model of livestock production, with limited use of human-edible feeds, is likely to be compatible with agricultural emissions targets, at least on an EU and UK level—providing, of course, meat and dairy consumption were to be reduced [56,57].

8. Conclusions

Cattle and sheep in the UK currently produce approximately 21.5 g of protein per person per day from grass and other forage crops, 45% of total UK edible animal protein production. This is in contrast to animal protein produced from systems that use large quantities of human-edible feed, a practice which increases productivity but often results in a net loss of nutrients for human consumption. Given the growing global demand for food and the need to produce this food in a more resource-efficient manner, grasslands and grazing animals have an important role to play in the provision of protein as well as other important nutrients for the human population.

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