Supporting Information

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SI Text

1. Overview

The method devised in this paper (depicted schematically in Fig. 1) permits partitioning of total resources used in and greenhouse gas (GHG) emissions associated with livestock production among the key edible animal categories: dairy, beef, poultry, pork, and eggs.

We begin by aggregating resources used [e.g., land, water, and reactive nitrogen (Nr)] by each individual feed type into the three feed classes: concentrated feed (i.e., concentrates), processed roughage (mostly hay and silage), and pasture (blue boxes in Fig. 1; and *SI Text*, sections 2 and 3). We then partition the resource aggregates for each feed class among the five animal categories using the partition coefficients devised by Eshel et al. in ref. 1 (upper red box in Fig. 1; and *SI Text*, sections 4 and 8) to determine total resources used in the production of each animal category (lower red box in Fig. 1; and *SI Text*, section 4). Finally, we divide total resources used per animal category by the US national caloric intake of that category, obtaining megacalorie resource efficiency per animal category for each of the three considered environmental metrics (yellow box in Fig. 1).

To derive the GHG burden of each animal category, we use published life cycle assessment (LCA) results of the production phase (including all relevant feed classes; *SI Text*, section 7). As a benchmark with which to compare the animal-based products' resource use, we devise the corresponding resource efficiency and GHG emissions of three common food plants (potato, wheat, and rice; *SI Text*, section 9).

All data and most supporting information calculations steps are fully documented and can be followed in Dataset S1, specific tabs and cells of which we reference in the text below. Dataset S1 also contains technical comments in specific cells, and specific reference points to data sources. [Dataset S1 comprises four main tabs that present the calculations' as the following key steps: (*i*) ResourceFeedMain, which is the starting point for all calculations, which summarizes the resources needed for feed production (land, water, and Nr), per feed type and class and the embodied calories of each feed type; (*ii*) PartitioningResource, which partitions all resource inputs among animal categories, e.g., total water or land needed for growing pork feed; (*iii*) PartitioningPerCal, which denotes resource use per human-consumed megacalorie in the United States by animal category; and (*iv*) PartitioningPerProtein, which denotes the resource use per human-consumed kilogram of protein in the United States by animal category.] Whereas the values in the main text appear in International System of Units format, the calculations presented here and in Dataset S1 are mostly in pounds (lb) or acres, conforming to US Department of Agriculture (USDA) nomenclature from which most data were derived.

2. Calculating the Resource Use of Individual Feeds

Our calculations are based on averaging the data available since 2000, typically (except for irrigation water) covering 2000–2011 or 2000–2012.

We summarize the resources used for each feed type included in the joint concentrates, processed roughage, and pasture feed classes in the ResourceFeedMain tab of Dataset S1. For simplicity we present a detailed, step-by-step numerical example of one feed or food category at the end of each subsection, along with the references from which the various data are derived.

Each feed class comprises several feed types (ResourceFeedMain tab in Dataset S1), where the two rightmost columns give the relevant national annual total and standard variation for that feed class (e.g., ResourceFeedMain tab columns Q and R for concentrates or Y and Z for processed roughage in the ResourceFeedMain tab in Dataset S1). This data are divided into feed (rows 4–9), needed land (rows 10–12), water (rows 16–17), fertilizer (rows 13–15), and feed calories produced (rows 18–19).

2.1. Feed Consumption by Feed Class. We start by presenting the feed consumed annually by all livestock (rows 4, 6, and 7 of the ResourceFeedMain tab in Dataset S1). The data presented are averages for the "feed and residual use" under the "domestic disappearance" category of the USDA. Data sources as indicated specifically for each dataset include USDA grain (2), oil (3) and wheat yearbooks (4), the 2011 Agriculture Statistics (5), and pasture (1) (see Dataset S1 for dynamic links to other tabs that present the raw data).

The soy calculations are an exception to this pattern. They comprise soy feed and residual use plus 60% of crushed (i.e., the caloric and economic fraction of crushed soybean that goes into soybean meal feed).

For example, the mean value of corn used for feed and residual in 2000–2011 is 5,557 million bushels (cell C4), with the corn tab presenting the raw data and calculations (column W). Cells C6 and C7 represent the total feed in millions of pounds and short tons, respectively.

Because dry matter (DM) content varies among feed types, before aggregation into feed classes and partitioning among animal categories we convert all data to a DM basis. Mean DM content (row 8) is the DM average of various feed forms (in the case of corn, e.g., corn grains rolled, corn grains whole, high-lysine corn grains, etc.) based on feed nutrient composition tables (see dynamic links to the FeedNutrientComposition tab in Dataset S1, based on ref. 6).

For corn, this yields 0.87 DM pounds per fed pound (cell C8). Hay, haylage, and greenchop deviate from this because USDA data for these are reported in a DM content equivalent assuming 13% moisture content. We therefore used 87% DM, not the nutrient composition table's mean. We calculate the total feed DM (row 9) as average feed mass multiplied by DM content. For corn (cell C9), this value is

$$\text{Feed DM}_{\text{corn}} = 0.87 \times 311{,}195 \times 10^6 \text{ lb} = 271{,}432 \times 10^6 \text{ lb}. \qquad \textbf{[S1]}$$

2.2. Land Use for the Various Feed Classes. We calculate feed land demands (feed needed land, row 12 of the ResourceFeedMain tab in Dataset S1) by dividing average consumed feed (in bushels, listed in the USDA nomenclature as "feed and residual use") by the average yield (bushel or mass) per planted acre (taking note of crop failures),

$$\text{Needed land} = \frac{\text{feed and residual use}}{\text{yield per planted acre}}. \quad \textbf{[S2]}$$

Because average yield is only available for harvested acreage, we calculate the yield per planted acre for each feed (row 10) using total production (in bushels or mass) and planted acres:

$$\text{Yield per planted acre} = \frac{\text{total production}}{\text{planted acres}}. \quad \textbf{[S3]}$$

The calculations are presented in the crop yields tab of Dataset S1 (for corn, sorghum, oats, and barely), soy table2 (for soy), and wheat (for wheat) (see dynamic links in the relevant cells of Dataset S1). Although in most cases the calculation is straightforward, to deduce corn's and sorghum's per planted acre yield for silage and grains, we must partition the planted acreage between the two products, and then divide the (known) production of each by its total planted acreage. This allocation is based on the harvested area of both products and is calculated in the following equation:

$$\text{Planted acreage}_{\text{grain}} = \frac{\text{harvested grain area} \times \text{planted acreage}}{\text{all-harvested area}}. \quad \textbf{[S4]}$$

A similar equation is used for silage. For corn, the mean total planted area is 83.3 million acres (crops yield tab, cell C20). The area harvested for grain is 75.9 million acres (cell I20) of a total of 81.6 million acres harvested (cell G20). The total corn grain planted area (cell H20) is therefore

$$\text{Planted acreage}_{\text{corn grain}} = 83.3 \times 10^6 \text{ acres} \times \frac{75.9}{81.6} \approx 76.6 \times 10^6 \text{ acres}. \quad \textbf{[S5]}$$

We then divide annual corn grain production (11,271 million bushels, cell J20) by this result, obtaining corn grain's yield of 147 bushels per planted acre (cell K20).

Needed land for pastureland is the sum of the reported "cropland used for pasture," "grassland pasture," and "grazed forest" of the USDA categories (pasture tab and ref. 7).

A final note regarding land use addresses the ≈4% of cropland producing more than one crop annually (7). These acres are counted twice: once for each crop (8). Therefore, to avoid double counting, all land used for crops (everything other than pasture) is scaled by a factor of 0.96 (ResourceFeedMain tab, cell Q12).

2.3. Fertilization of the Various Feeds. Nitrogen fertilization data for corn, wheat, and soy are from the USDA Economic Research Service, Fertilizer Use and Price (9), whereas for barley, oats, and sorghum the source is USDA Economic Research Service, National Agriculture Statistics Service Quick Stats (10).

The mean Nr application rate per planted acre for each feed type (ResourceFeedMain tab, row 13 in Dataset S1) is calculated by dividing the feed type's total annual applied nitrogen (ConcentratesNr tab in Dataset S1) by its total planted acreage [the actual percentage of land fertilized also appears in the specified tab (e.g., for corn, in columns C–F of ConcentratesNr)]:

$$\text{Nr per planted acre} = \frac{\text{total Nr applied}}{\text{planted acreage}}. \quad \textbf{[S6]}$$

On average $4{,}956 \times 10^3$ (short) tons of Nr are applied on corn (grain) fields annually (cell C19), which, spread over the full 76.6 million planted acres of corn, yields a mean application rate of 129 lb $(\text{acres} \times \text{y})^{-1}$ (cell E21).

Based on the calculated needed land and mean Nr application rate, total applied Nr for each feed type is (ResourceFeedMain tab, row 15 in Dataset S1)

$$\text{Total Nr}_{\text{feed}} = \text{needed land}_{\text{feed}} \times \text{Nr per planted acre}_{\text{feed}}. \quad \textbf{[S7]}$$

Concentrated data on nitrogen use for pasture, hay, or silage are unavailable. We did however find data on total fertilized pastureland acreage (with no details as to fertilizer type; ref. (10) (in the ResourceFeedMain tab, cell AA14 in Dataset S1). Therefore, to estimate total pasture Nr use (ResourceFeedMain tab, cell AA15), we multiply the total area of pastureland fertilized by Nr application recommendations from the Natural Resources Conservation Service (cell AA13) (11).

To assess the amount of Nr used for all processed roughage (cell Y15) we subtract all known uses of Nr (grains, vegetable, fruit and nuts, and our result for pastureland) from the total Nr applied in the United States:

$$\text{Total Nr}_{\text{roughage}} = \text{total US Nr use} - \text{all known Nr use}. \quad \textbf{[S8]}$$

2.4. Irrigated Water Used for the Various Feed Types. Irrigation data were obtained from the 2008 Farm and Ranch Irrigation Survey, which reports average irrigation rates per harvested–irrigated acre in the years 2002–2003 and 2007–2008 (12).

To calculate mean irrigation rates per planted acre (irrigated and nonirrigated; ResourceFeedMain tab, row 16 in Dataset S1), we divide each crop's total water use (total irrigated acres × mean irrigation rate) by its planted acreage (water tab),

$$\text{Mean water irrigation rate} = \frac{\text{irrigated\&harvested acreage} \times \text{irrigation rate}}{\text{planted acres}}, \quad \textbf{[S9]}$$

and then obtain the crop's total water needs (ResourceFeedMain tab, row 17) using

$$\text{Total water}_{\text{feed}} = \text{mean water irrigation rate}_{\text{feed}} \times \text{needed land}_{\text{feed}}. \qquad \textbf{[S10]}$$

For example, in 2007–2008, 12 million acres of corn grain were irrigated and harvested, with a reported average irrigation rate of 1 acre-foot, or 1,234 m^3 per harvested–irrigated acre (water tab, cell F18). That year, corn grain's total planted acreage (irrigated and nonirrigated) was 87.4 million acres (cell C18). Therefore, corn's 2007 irrigation rate per planted acre (cell H18) was

$$\frac{12\times10^6 \text{ acres} \times 1{,}234\text{m}^3/(\text{acre}\times\text{y})}{87\times10^6 \text{ acres}} \approx 169\,\frac{\text{m}^3}{\text{acre}\times\text{y}}. \qquad \textbf{[S11]}$$

Averaged with 2003 data (the only other irrigation data point available since 2000), this becomes 185 $m^3/(\text{acre}\times\text{y})$ (cell H24).

As no sorghum silage irrigation data exist, we assume sorghum's mean irrigation rate is that of corn silage.

We then proceed to multiply this average irrigation rate per planted acre by the total land required for corn grain feed production (37.9 million acres) to arrive at total annual water requirement for corn grain (7,022 million m^3/acre, ResourceFeedMain tab, cell C17).

2.5. Feed Calories Derived from Various Feeds. We calculate the energy content (kilocalories per pound) of the various feed types (ResourceFeedMain tab, row 18 in Dataset S1) based on feed composition tables (6) (see data presented in the FeedNutrientCompostion tab in Dataset S1), using

$$\text{DE} = \%\text{TDN} \times 0.02, \qquad \textbf{[S12]}$$

where DE is the digestible energy in megacalories per pound (Mcal = 10^3 kcal), and % TDN is the mean percentage of total dry nutrient in the various forms of a given feed. We estimate pasture value as the average of wheat (6), grass, and legume forage pastures (13). (An online calculator with the grass and legume forage pasture values appears in ref. 13.) The total calories contributed by a specific feed type (row 19) is the total feed dry mass (row 9) times its energy content (row 18).

Corn is used in various forms (e.g., rolled grain, screenings) with an average TDN of 85%. Its mean energy content is therefore $85\times0.02 = 1.7$ Mcal/lb (cell C18).

With a total corn grain DM consumption of $271{,}432\times10^6$ lb (cell C9), livestock consume $271{,}432\times10^6$ lb $\times$ 1.71 Mcal/lb $\approx 463{,}939\times10^6$ corn grain megacalories per year (cell C19).

3. Aggregating Individual Feed Type Results into Feed Classes

The next step is aggregating (summing) the various individual feed type resource use into the three feed classes: concentrates (ResourceFeedMain tab, column Q in Dataset S1), processed roughage (column Y), and pasture (column AA). The sums are feed DM intake (row 9), needed land (row 12), Nr fertilizer used (row 15), irrigated water (row 17), and calories produced (row 19).

4. Partitioning Environmental Burdens Among Animal Categories (Including Export–Import Correction)

To allocate the resource use to each animal category, we multiply each feed class sum by the portion of feed each individual animal category consumes from the total using coefficients derived by Eshel et al. (1) (see the Animal Partitioning tab, cells D7:J14 in Dataset S1 and *SI Text*, section 8 for coefficients). This step first requires two minor intermediate corrections, as follows.

First, we adjust total resources used to reflect only what is required for the animal categories which we analyze in this study (dairy, beef, poultry, pork, and eggs that we term the "edibles") which contribute substantially to the mean American diet. Because the presented resource use sums reflect requirements also for other livestock, including those whose contributions to the mean American diet is zero or minute (i.e., nonedibles: horses, sheep, goats), we multiply the results by a coefficient derived by Eshel et al. (1) that removes those feed requirements. The major edible coefficients are 98.07% (PartioningResources tab, cell B15) for concentrates, 95.21% (cell B16) for processed roughage, and 92.2% (cell B17) for pasture. The results for the edible animal categories' resource needs by feed class appear in the Partioning-Resources tab, cells A3:AF10 in Dataset S1. For example, beef's land needs for production of concentrates (abbreviated as "con."; cell C6) is

$$\begin{aligned}\text{Land con.}_{\text{beef}} &\equiv (\text{total needed land}_{\text{con.}}) \times (\text{beef's \% of con.}) \times \left(\frac{\text{edible con.}}{\text{total con.}}\right)\\ &= 78\times10^6\,\frac{\text{acre}}{\text{y}} \times 24.1\% \times 0.9807 = 18\times10^6\,\frac{\text{acre}}{\text{y}}.\end{aligned} \qquad \textbf{[S13]}$$

Second, because there are export–import imbalances in livestock products, we adjust inputs to reflect only domestic consumption. To that end, we multiply the total resource needs of each animal category by the fraction of total production consumed domestically (cells B21–B25) (14, 15).

For example, the total land used by beef adjusted for domestic disappearance (cell K6) is then

$$\begin{aligned}\text{Total land}_{\text{beef}} &\equiv \text{total needed land}_{\text{beef}} \times \left(\frac{\text{domestic disappearance of beef}}{\text{total beef production}}\right)\\ &= 741\times10^6\,\frac{\text{acre}}{\text{y}} \times 104\% = 770\times10^6\,\frac{\text{acre}}{\text{y}}.\end{aligned} \qquad \textbf{[S14]}$$

Where the value of 104% indicates that there is net import (minus export) of beef that amounts to 4% of the US national beef production and the total land resources need to be increased to account for that. To derive the resource use intensity per eaten kcal of each animal category, we divide the total resources used by each category by its national caloric de facto consumption,

$$\text{Resource use intensity} = \frac{\text{domestically adjusted annual resource use per animal category}}{\text{annual total US population caloric consumption of animal category}}. \quad \textbf{[S15]}$$

These final results, reported in cells A12:P18 of the PartitioningPerCal tab in Dataset S1, are the present paper's main results.

Annual national net caloric consumption (USA Cal-Protein Intake tab, cells E25:O25 in Dataset S1) are the products of mean daily loss adjusted per capita intakes (columns E, G, I, K, and M) (16), total US population (column P) (16), and 365.2 $d \cdot y^{-1}$.

For example, we obtain beef's water use in liters per eaten megacalorie (PartitioningPerCal tab, cell E14 in Dataset S1) by dividing beef's total water use (PartitioningResources tab, cell U6) by beef's national adjusted de facto caloric consumption (USA Cal-Protein Intake tab, cell F25),

$$\text{Water use}_{\text{beef}} = \frac{1{,}000\left(\text{L}/\text{m}^3\right) \times 34{,}924 \times 10^6\ \text{m}^3/\text{y}}{21{,}267 \times 10^6\ \text{Mcal}/\text{y}} = 1{,}642\,\frac{\text{L}}{\text{Mcal}}. \quad \textbf{[S16]}$$

5. Allocation Issues

In calculating the burden per calorie for all of the categories we take into account that although slaughtered dairy cattle and laying hens have consumed during their lifetime feed from the dairy and egg categories, their slaughtered meat calories contribute to the beef and poultry categories, respectively. We thus partition their lifetime-consumed feed between the two relevant animal categories to faithfully reflect the feed related environmental costs each incurred.

The allocation procedure is based on calculating slaughtered dairy's feed consumption of each feed type and adding them to the beef category. We also apply a logically identical procedure to partition concentrated feed consumed by slaughtered laying hens between the egg and poultry categories. This procedure attributes the feed that would have been needed to produce the same mass of the corresponding meat types using the relevant meat categories' representative practices. Because the use of this feed was avoided, we refer to the cost reduction in the dairy and eggs categories as avoided costs. This partitioning of feed between the animal category pairs alters the partitioning coefficients of environmental costs among the animal categories (*SI Text*, section 8). We then use these new coefficients—now taking note of avoided feed costs—to carry out all subsequent calculations (Animal Partitioning tab, cells D7:J14 in Dataset S1).

Data on beef calories consumed take into account slaughtered dairy cattle (8.5% by mass; USA Cal-Protein Intake tab, cells F36:G38 in Dataset S1, based on Eshel et al., ref. 1). We multiplied this percentage value with beef's total DM feed and derived culled dairies' feed requirement. This total feed requirement was then divided between the various feed types according to dairy's feed type fractions (i.e., 60% for concentrates, 28% for processed roughage, and 12% for pasture). With the absolute amount of feed per feed type established, we then credited (subtracted) the dairy category and added these same values to beef's three feed types accordingly.

We use the same rationale as described above to credit the egg category's resources use by subtracting slaughtered layers' DM feed contribution per feed type from the egg category and adding them to the poultry category. First, we calculate the mass of slaughtered hens (layers) ($\approx$1.7% from total poultry slaughtered; USA Cal-Protein Intake tab, cell G41) and multiplied it by poultry's feed intake per slaughtered pound. Normally, this feed requirement should be credited from the egg category and added to the poultry category. However, because only about 35% of these slaughtered hens (termed spent hens) are actually consumed by humans (17), the total feed requirement should be additionally multiplied by this value. Consequently, this resulted in crediting egg total feed intake by less than 3%; thus we neglected this allocation.

6. Protein-Based Partitioning of Environmental Burdens

As discussed in the *Results* section of the main text, for some applications the environmental costs per unit protein consumed is a more illuminating metric. In all cases, it is an important complement to the results per ingested megacalorie reported in Fig. 2. In Fig. S1 we therefore recast Fig. 2 (this paper's key result) in terms of environmental costs per kilogram of protein (see also the PartitioningPerProtein tab in Dataset S1). We derive national consumption of animal protein (against which the environmental burdens are compared; USA Cal-Protein Intake tab, cells R25:AB25 in Dataset S1) by dividing national caloric intakes by the corresponding $\text{Mcal}\cdot\text{kg}^{-1}$ of the various animal categories (USA Cal-Protein Intake tab, cells R23:AA23), and multiplying them by the categories mass protein percentages (18) (done in USA Cal-Protein Intake tab, cells R24:AB24).

7. GHG Emissions of the Various Animal Categories

We obtain GHG use intensity in kilograms of CO_{2e} emissions per edible megacalorie from LCA studies that quantify the GHG emissions associated with the production of animal-based products, taking note of all production aspects up to farm gate (from "cradle to farm gate"). These include feed production (carbon dioxide and nitrous oxide), enteric fermentation for beef, dairy and pig (methane), and manure excretion (methane and nitrous oxide) with the relative contribution of each constituent and its absolute value varying according to animal type, location (climate), and agrotechnological practice. To be consistent with the other data sources, we favored US studies, but also incorporated non-US values which presented a wide range of results (meta-analysis) for statistical robustness. The calculations and refs. 19–27 are reported in the GHG Animals tab in Dataset S1. The results also appear in the PartitioningPerCal tab, cells H13:J18 in Dataset S1.

Beef's GHG use per megacalorie values are based on the average of four studies (GHG Animals tab, cells B14:C21 in Dataset S1), three (19–21) reporting emissions per live weight (cells C16–C18), and one (22) per edible kilogram (cell C19). To recast the former three values as emissions per edible kilogram, we divide them by the boneless edible fraction of total beef mass, 43% (19, 22),

$$\text{GHG emission per edible kg}_{\text{beef}} = \frac{\text{kg CO}_{2\text{e}}/(\text{live weight kg})}{\text{boneless fraction from total mass}}. \quad \textbf{[S17]}$$

We then average the four derived and directly reported values, yielding cell's C20 result, 32 kg CO_{2e}/(edible kg). To convert edible kilograms to megacalories we use 1.52 Mcal/lb (cell H9), obtained by dividing national total caloric intake of beef with boneless weight national consumption, yielding

$$\text{GHG intensity}_{\text{beef}} = \frac{32.15\ \text{kg CO}_{2\text{e}}/(\text{edible kg})}{(1.52\ \text{Mcal/lb}) \times (2.204\ \text{lb/kg})} = 9.6\,\frac{\text{kg CO}_{2\text{e}}}{\text{Mcal}} \qquad \textbf{[S18]}$$

in the GHG Animals tab, cell C21 and PartitioningPerCal tab, cell H14 in Dataset S1.

8. Partitioning Coefficients

Motivated by the disproportionate environmental costs of animal-based categories mentioned above, we devise such a method expressly for US livestock. Because costs incurred downstream of the farm gate (processing, packaging, retail, and household) exhibit modest variations among the various livestock products (22), we base our method on partitioning feed consumption. We devise a method to partition a given food-related total environmental burden—say water or land use—into the fractions attributable to specific food categories (1). First, we calculate overall feed requirements of each livestock category by combining extensive data on headcounts, slaughter weights, and per head and per slaughtered weight feed requirements. We then combine these requirements with the USDA estimates of overall US feed production and availability by type considering concentrates and roughage subdivided into pasture and processed roughage: hay, silage, haylage, and greenchop. Taken together, these data yield our feed requirement estimates for each category and feed class, which constitute the required partitioning (1). These results (following the allocation procedure described in *SI Text*, section 5) together with their SD appear in both the Animal Partitioning tab, cells D6:J14 in Dataset S1 and in Table S1.

9. Plant Resource Use and GHG Emission Calculations

Resource use and GHG emissions by plant items per megacalorie and kilogram of protein are summarized in the PartitioningPerCal tab, cells A38:E44 and PartitioningPerProtein tab, cells I36:M42, respectively, in Dataset S1. The per megacalorie values are based on comparing plants' per acre planted yield (4, 5, 28), water use (12), and nitrogen application (10) with their energy content (megacalories per pound), derived from the National Nutrient Database for Standard References (29). For instance, we calculate potatoes' average annual yield by dividing total production, ≈44 billion lb per y, by total acreage of 1.2 million acres resulting in 37,950 lb/(acre × y) (5). Potatoes' loss adjustment factor (the ratio of ingested to produced, in the USDA's Loss-Adjusted Food Availability Documentation) (30) and energy content (29) are 0.75 and 350 kcal/lb, respectively. Therefore, potatoes' land use intensity is (PartitioningPerCal tab, cell B42 in Dataset S1)

$$\text{Land use}_{\text{potato}} = \frac{4{,}046{,}860 \times 10^{-3}\ \text{m}^2/\text{acre}}{[37{,}950\ \text{lb}/(\text{acre} \times \text{y})] \times 0.75 \times (350\ \text{kcal/lb})} = 0.41\,\frac{\text{m}^2 \times \text{y}}{\text{loss-adjusted Mcal}}. \qquad \textbf{[S19]}$$

The average irrigation of harvested potatoes is 1.8 acre-foot/(acre × y) (12). Multiplying this value by the total harvested area and then dividing by the total planted area results in a water use per planted acreage of 1,971 m^3/(acre × y) (this calculation is not shown in Dataset S1).

Subsequently, the potato's water use intensity per loss-adjusted megacalorie is (PartitioningPerCal tab, cell C42 in Dataset S1)

$$\text{Water use}_{\text{potato}} = \frac{1{,}000\ \text{kcal/mcal}}{\{[37{,}950\ \text{lb}/(\text{acre} \times \text{y})] \times 0.75 \times (350\ \text{kcal/lb})\}/[1{,}971\ \text{m}^3/\text{acre} \times \text{y}]} = 0.20\,\frac{\text{m}^3}{\text{loss-adjusted Mcal}}. \qquad \textbf{[S20]}$$

Potatoes' mean annual Nr fertilization rates are obtained by dividing total application amounts for 2001, 2003, 2005, and 2010 (10) (the only available data since 2000) by the planted acreage resulting in 160 lb/(acre × y). Therefore, potato's nitrogen use intensity is (PartitioningPerCal tab, cell E42)

$$\text{Nitrogen use}_{\text{potato}} = \frac{453{,}592 \times 10^{-3}\ \text{g/lb}}{\{[37{,}950\ \text{lb}/(\text{acre} \times \text{y})] \times 0.75 \times (350\ \text{kcal/lb})\}/[160\ \text{lb Nr}/(\text{acre} \times \text{y})]} = 7.30\,\frac{\text{g Nr}}{\text{loss-adjusted Mcal}}. \qquad \textbf{[S21]}$$

With no data on GHG emissions of US plants, we use data from a UK-based study (31) that evaluated the GHG emissions of food production in the United Kingdom, the "European Union (EU) for UK consumption," and "the rest of the world for UK consumption." Our first choice was to use EU values as they average over various countries and climates, not unlike the United States. When such values were not available (e.g., for rice), we used the rest-of-the-world value. Unlike the animal-based GHG emissions values, which address emissions up to farm gate, plant GHG emissions also consider emissions up until the regional distribution center.

Using a GHG emission value of 0.51kg CO_{2e} per kilogram of potato, a loss adjustment factor of 0.75, an energy content of 350 kcal/lb (as above), and with the appropriate unit conversion ratios reveal the potato's GHG emission intensity (PartitioningPerCal tab, cell D42)

$$\text{GHG intensity}_{\text{potato}} = \frac{(0.51\ \text{kg CO}_{2\text{e}}/\text{kg commodity}) \times (1{,}000\ \text{kcal/Mcal})}{(2.2\ \text{lb/kg}) \times 0.75 \times (350\ \text{kcal/lb})} = 0.88\,\frac{\text{kg CO}_{2\text{e}}}{\text{loss-adjusted Mcal}}. \qquad \textbf{[S22]}$$

In conclusion, we present the resource intensity uses and GHG emission burdens of the animal-based categories relative to three plant-based staple crops (including potatoes) in Fig. S2.

10. Uncertainty Estimates

We use SD as our uncertainty measure. Typical uncertainty estimates combine, additively or multiplicatively, several more basic terms. Consequently, full uncertainty estimates typically involve (*i*) determination of the individual uncertainty characteristic of each participating term; and (*ii*) propagating those individual uncertainties into a single final uncertainty measure using traditional uncertainty propagation rules for sums and products.

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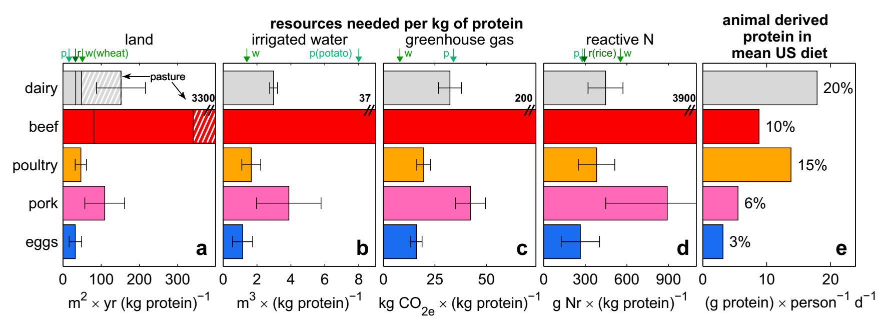

Fig. S1. The main results of this paper are plotted as resource use (land, irrigated water, and Nr) and emission (GHG) per animal kilogram of protein consumed (*A*–*D*). *E* details the national daily average per capita of animal protein intake and the relative contribution (percentage) of each animal category to mean US total protein intake of an adult. In *B*, the arrow denoting rice's water requirement per kilogram of protein is missing from the top of the panel [similar to wheat (w) and potato (p)] because its value of 21 m^3/kg of protein is above the indicated scale (0–9). The same is true for rice's GHG intensity (*C*) of 87 kg $CO_{2}e$/kg protein exceeding the indicated scale (0–75).

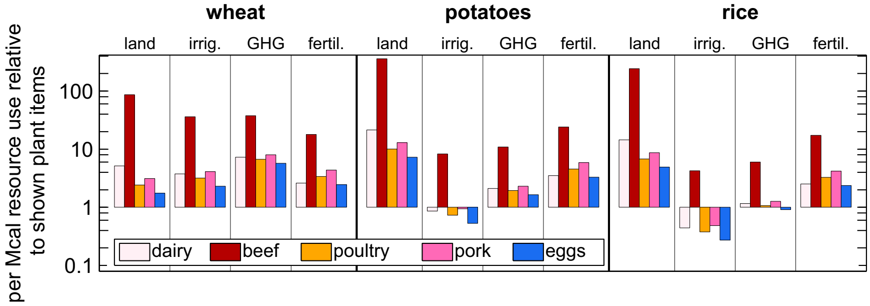

Fig. S2. Per megacalorie resource intensity uses and GHG emission burdens of the animal-based food categories relative to the three different crop plants. irrig, irrigation; fertil., nitrogen fertilization.

Table S1. The partition coefficients (%) of feed classes derived by Eshel et al. (1)

	Pasture		Processed roughage		Concentrates	
Feed class	Mean	SD	Mean	SD	Mean	SD
Dairy	8	3	13	3	24	4
Beef	92	3	87	3	21	11
Poultry	0	0	0	0	27	5
Pork	0	0	0	0	23	9
Eggs	0	0	0	0	4	2

SD, standard deviation.

Other Supporting Information Files

Dataset S1 (XLSX)