Current global food production is sufficient to meet human nutritional needs in 2050 provided there is radical societal adaptation

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Supplementary Information (Elementa, 2018)

S1. Details of methods used

Data from the Food and Agricultural Organisation (FAO) Food Balance Sheets and Commodity Balance Sheets for 2013 (Food and Agriculture Organisation of the United Nation , 2016) are divided by the global (7.18×10^9) and regional populations for that year and by the projected global (9.7×10^9) population (United Nations, 2015) for 2050 and by the number of days in a year to determine edible crop production (E_h), meat (including fish) and dairy production (M_p) and non-food uses (N) per capita per day. Meat, dairy and fish production is separated from edible crop production by assigning FAO's food categories to one or the other. Since the Food Balance Sheets do not include all human-edible animal feeds (such as seed cakes and brans), we obtain these from the FAO's Commodity Balances. We convert from the mass-based data presented by the FAO to energy, protein and micronutrients by using nutritional values for 106 food and feed types. Energy and protein values are taken from the FAO Food Balance Sheets Handbook (Food and Agriculture Organisation of the United Nations, 2001) where possible. Micronutrient data are largely taken from USDA (United States Department of Agriculture, 2017). All values are expressed in quantities per person per day (e.g. kcal/p/day) and exclude any fortification.

We do not use the Balance Sheet waste data since it is incomplete and aggregated. Instead, we calculate harvest losses (L_h), post-harvest losses (L_{ph}), processing losses (L_p), distribution losses (L_d) and consumer waste (L_c) using the FAO's regionally-averaged, mass-based food losses for seven food groups (Lundqvist et al., 2008). We apply these to the food types used and convert from mass to nutrient as described above.

The edible crop grown (E_g) is derived from $E_g = E_h + L_h$ and the crop available for use (E_{au}) from $E_{au} = E_h - L_{ph} + I_m - E_x$, where I_m and E_x are the imports and exports. At the global level the difference between imports and exports is the international trading losses, given by $L_t = E_x - I_m$. Of E_{au}, the available crop directed toward the human food supply chain is

obtained by subtraction of the human-edible crops fed to animals (F_c), available crops which are re-sown or replanted (i.e. invested, I), and crops diverted to non-food uses (N), such that $E_{cah} = E_{au} – F_c – I – N$.

The values for I and N are also obtained from the FAO Food Balance Sheets for 2013. F_c is derived by adding the Balance Sheet data on cereals fed to animals with oilcake and bran data from the Commodity Balances. The energy content of feed cakes is established using multipliers which convert production values back to their primary crop equivalents (Davis and D'Odorico, 2015). We assume other nutrients are transferred to the cake from the raw crop, and adjust the intensities by the crop-to-cake weight ratios.

An alternative estimate of the amount of human-edible crops fed to animals (F_{c2}) is derived from a detailed study of animal nutritional inputs in 2000 broken down into nine global regions, four animal types, three animal products and eight production systems (Tilman and Clark, 2014). This is more detailed than the data feeding into the FAO Balance Sheets used elsewhere in this analysis, and so provides a good cross-check of our method. However, an adjustment is required to take account of the 27% increase in meat and dairy production between 2000 and 2013, derived from the food Balance Sheets for those years. To do this we assume that grass, pasture and stover (GP&S) inputs to animals increased in the same ratio as meat and dairy production outputs. This method leads to F_{c2} = 1850 kcal/p/d, which compares with the figure we derive from the FAO Balance Sheets of 1738 kcal/p/d.

The total food delivered to consumers (E_d) is derived by adding the available human-edible crops to the meat, fish and dairy production and subtracting the processing and distribution losses, i.e. $E_d = E_{cah} + M_p - L_p - L_d$. The total food eaten by humans (E) is simply the food delivered to consumers less the consumer waste, i.e. $E = E_d – L_c$.

Energy delivered to animals from GP&S (F_g) is estimated using the FAO Food Balance Sheet data and published metabolic energy contents of feed for different livestock species and production systems[23] and the calorific content of feed cake (Davis and D'Odorico, 2015). F_g is calculated as the product of weighted-average metabolic energy (MJ/kg feed) and tonnes of feed from non-grain sources. Animal metabolic energy losses (L_a) are estimated from the energy flows to and from animals, $L_a = F_c + F_g - M_p$. We estimate the protein delivered to animals from GP&S using the average protein to metabolisable energy ratio for 14 types of grass (Pennsylvania State University, 2003).

We use the FAO weighted-average dietary energy requirement (ADER)[19] for the global average calorific intake required for healthy life (R) (2353 kcal/p/d). The ADER for each region is derived from national ADER values, which vary with body size, activity level, age and gender, calculated using the FAO methodology (World Health Organization & Food and Agriculture Organization of the United Nations, 2001), with results taken from Our World in Data (2017). For protein, vitamin A, iron and zinc, we calculate population-weighted global and regional average recommended daily intakes using the Recommended Dietary Allowance (National Research Council, 1989) and Reference Nutrient Intake (British Nutrition Foundation, 2016) values, which vary by age, gender, pregnancy and breastfeeding status. Data from these latter parameters were obtained from the United States Census Agency (2013) and World Health Organisation (2013).

Net excess human consumption (X) is given by $X = E - R$. Total food waste (W_t), excluding the metabolic and other losses inherent in animal husbandry and excluding net excess human consumption, is given by $W_t = L_h + L_{ph} + L_t + L_p + L_d + L_c$.

To construct our notional 'healthy diet' used in Table 1, we use the minimum or maximum intakes of fruit and vegetables, sugar and sweeteners, vegetable oils and meat and dairy as specified by the FAO/WHO (World Health Organisation & Food and Agriculture Organisation of the United Nations, 2003), Harvard Medical School (Willett, 2001) and the American Heart Association (2014).

The disaggregated data on food energy and protein waste shown in Table S1 are calculated using our analysis of total waste at each stage in the supply chain and FAO data (Food and Agriculture Organisation of the United Nations, 2011) on food losses and food waste by mass broken down by seven geographic regions and seven food groups. We convert from mass to energy and protein using the method described above.

S2. Data and analysis

The Excel workbook containing our data and analysis is freely available at https://dx.doi.org/10.17635/lancaster/researchdata/222.

S3. Discussion of uncertainties

We recognise a number of uncertainties in our analysis although are unable to order these by potential significance: (i) we take the FAO food Balance Sheet and Commodity Balances data to be accurate despite their known but unquantified deficiencies; (ii) the values used for global and regional populations in 2013 and 2050; (iii) the assumption that the nutrient density of a specific crop is the same whether grown for and eaten by humans or animals; (iv) the nutrient density conversion factors used for food types and feed cakes; (v) the assumption that waste rates are uniform across the food types within each of the five food groups within each geographic region; (vi) the approximation in our scenarios that total meat and dairy output is proportional to animal metabolisable energy inputs whether these are from human-edible crops or from grass, pasture and stover; (vii) in the calculation of net excess consumption, we assume that the FAO weighted-average dietary energy requirement is accurate and will remain the same in 2050, despite the trends for increasing body mass and sedentary lifestyles; and (viii) we assume the integrity of vitamin A remains unchanged throughout the food chain.

As a second check of our methodology and the data used, we compare E with the FAO estimate of food eaten based on household surveys (Food and Agriculture Organisation of the United Nations, 2016). The two differ by 112 kcal/p/d (5%). It is known that in some societies under-reporting consumption is common while in others over-reporting is common.

S4. Food waste by stage and food type at the regional and global levels

Table S1: Food wastes by stage and food type at the regional and global levels for energy (a and b) and protein (c and d). a and c express waste in terms of the quantity per person within each region while b and d express waste as the percentage of all food waste of each nutrient at the global level. The green to red shading denotes least to most significant sources of waste at the global scale.

a) Food energy waste (kcal/p/day)

	Harvest	Post-harvest	Processing	Distribution	Consumer	Total
Europe inc Russia	**131**	**111**	**103**	**36**	**210**	**591**
Cereals	48	95	69	12	144	368
Fish and seafood	0	0	1	2	2	5
Fruits and vegetables	15	3	2	8	14	41
Meat	0	0	11	9	23	43
Milk	0	0	2	1	14	17
Oilseeds and pulses	42	4	9	2	7	64
Roots and tubers	26	9	8	3	7	53
Industrialised Asia	**65**	**134**	**86**	**39**	**140**	**465**
Cereals	23	115	58	10	97	303
Fish and seafood	0	0	2	4	2	8
Fruits and vegetables	16	11	2	10	17	56
Meat	0	0	9	11	13	33
Milk	0	0	1	0	3	4
Oilseeds and pulses	4	2	6	1	5	18
Roots and tubers	22	6	7	4	4	42
Latin America	**216**	**125**	**108**	**53**	**83**	**583**
Cereals	127	79	62	25	60	353
Fish and seafood	0	0	1	1	0	3
Fruits and vegetables	27	11	12	6	4	60
Meat	0	0	8	8	9	24
Milk	0	0	2	8	4	13
Oilseeds and pulses	49	23	17	4	4	97
Roots and tubers	13	11	5	1	1	32
North Africa, West and Central Asia	**101**	**95**	**119**	**58**	**108**	**480**
Cereals	59	74	76	31	88	328
Fish and seafood	0	0	1	1	0	2
Fruits and vegetables	22	11	19	12	8	72
Meat	0	0	4	3	5	12
Milk	0	0	2	7	2	11
Oilseeds and pulses	17	6	14	3	3	43
Roots and tubers	3	4	3	1	1	13
North America and Oceania	**281**	**106**	**140**	**45**	**328**	**900**
Cereals	100	98	100	17	226	542
Fish and seafood	0	0	1	2	5	8
Fruits and vegetables	13	2	2	10	21	48
Meat	0	0	13	10	26	50
Milk	0	0	2	1	29	32
Oilseeds and pulses	155	0	16	3	12	185
Roots and tubers	12	5	6	2	9	34
South and Southeast Asia	**99**	**123**	**52**	**31**	**24**	**328**
Cereals	56	62	22	12	18	170
Fish and seafood	0	0	1	2	0	4
Fruits and vegetables	11	6	13	4	3	37
Meat	0	0	2	2	1	5
Milk	0	0	1	6	1	8
Oilseeds and pulses	28	44	10	2	1	85
Roots and tubers	4	12	2	2	1	20
Sub Saharan Africa	**119**	**123**	**68**	**32**	**11**	**354**
Cereals	38	48	20	11	5	123
Fish and seafood	0	0	1	1	0	3
Fruits and vegetables	7	6	12	6	1	33
Meat	0	0	2	2	1	5
Milk	0	0	0	3	0	3
Oilseeds and pulses	25	15	12	3	1	56
Roots and tubers	49	54	21	6	2	132
World	**118**	**122**	**81**	**38**	**95**	**453**
Cereals	55	80	46	14	67	262
Fish and seafood	0	0	1	2	1	5
Fruits and vegetables	14	7	9	7	8	46
Meat	0	0	6	6	8	20
Milk	0	0	1	4	4	9
Oilseeds and pulses	32	20	10	2	4	68
Roots and tubers	17	14	7	3	3	44

b) Energy waste (proportion of the world total waste)

	Harvest	Post-harvest	Processing	Distribution	Consumer	Total
Europe inc Russia	**3.1%**	**2.6%**	**2.4%**	**0.9%**	**5.0%**	**13.9%**
Cereals	1.1%	2.2%	1.6%	0.3%	3.4%	**8.7%**
Fish and seafood	0.0%	0.0%	0.0%	0.0%	0.0%	**0.1%**
Fruits and vegetables	0.4%	0.1%	0.0%	0.2%	0.3%	**1.0%**
Meat	0.0%	0.0%	0.3%	0.2%	0.5%	**1.0%**
Milk	0.0%	0.0%	0.1%	0.0%	0.3%	**0.4%**
Oilseeds and pulses	1.0%	0.1%	0.2%	0.0%	0.2%	**1.5%**
Roots and tubers	0.6%	0.2%	0.2%	0.1%	0.2%	**1.3%**
Industrialised Asia	**3.2%**	**6.6%**	**4.2%**	**1.9%**	**6.9%**	**22.8%**
Cereals	1.2%	5.6%	2.8%	0.5%	4.7%	**14.9%**
Fish and seafood	0.0%	0.0%	0.1%	0.2%	0.1%	**0.4%**
Fruits and vegetables	0.8%	0.6%	0.1%	0.5%	0.8%	**2.7%**
Meat	0.0%	0.0%	0.5%	0.5%	0.7%	**1.6%**
Milk	0.0%	0.0%	0.0%	0.0%	0.1%	**0.2%**
Oilseeds and pulses	0.2%	0.1%	0.3%	0.1%	0.2%	**0.9%**
Roots and tubers	1.1%	0.3%	0.4%	0.2%	0.2%	**2.1%**
Latin America	**4.2%**	**2.4%**	**2.1%**	**1.0%**	**1.6%**	**11.4%**
Cereals	2.5%	1.5%	1.2%	0.5%	1.2%	**6.9%**
Fish and seafood	0.0%	0.0%	0.0%	0.0%	0.0%	**0.1%**
Fruits and vegetables	0.5%	0.2%	0.2%	0.1%	0.1%	**1.2%**
Meat	0.0%	0.0%	0.2%	0.1%	0.2%	**0.5%**
Milk	0.0%	0.0%	0.0%	0.2%	0.1%	**0.3%**
Oilseeds and pulses	1.0%	0.4%	0.3%	0.1%	0.1%	**1.9%**
Roots and tubers	0.3%	0.2%	0.1%	0.0%	0.0%	**0.6%**
North Africa, West and Central Asia	**1.4%**	**1.3%**	**1.7%**	**0.8%**	**1.5%**	**6.7%**
Cereals	0.8%	1.0%	1.1%	0.4%	1.2%	**4.6%**
Fish and seafood	0.0%	0.0%	0.0%	0.0%	0.0%	**0.0%**
Fruits and vegetables	0.3%	0.2%	0.3%	0.2%	0.1%	**1.0%**
Meat	0.0%	0.0%	0.0%	0.0%	0.1%	**0.2%**
Milk	0.0%	0.0%	0.0%	0.1%	0.0%	**0.1%**
Oilseeds and pulses	0.2%	0.1%	0.2%	0.0%	0.0%	**0.6%**
Roots and tubers	0.0%	0.1%	0.0%	0.0%	0.0%	**0.2%**
North America and Oceania	**3.4%**	**1.3%**	**1.7%**	**0.5%**	**4.0%**	**10.9%**
Cereals	1.2%	1.2%	1.2%	0.2%	2.7%	**6.6%**
Fish and seafood	0.0%	0.0%	0.0%	0.0%	0.1%	**0.1%**
Fruits and vegetables	0.2%	0.0%	0.0%	0.1%	0.3%	**0.6%**
Meat	0.0%	0.0%	0.2%	0.1%	0.3%	**0.6%**
Milk	0.0%	0.0%	0.0%	0.0%	0.4%	**0.4%**
Oilseeds and pulses	1.9%	0.0%	0.2%	0.0%	0.1%	**2.2%**
Roots and tubers	0.2%	0.1%	0.1%	0.0%	0.1%	**0.4%**
South and Southeast Asia	**7.5%**	**9.3%**	**3.9%**	**2.4%**	**1.8%**	**24.9%**
Cereals	4.2%	4.7%	1.7%	0.9%	1.4%	**12.9%**
Fish and seafood	0.0%	0.0%	0.1%	0.2%	0.0%	**0.3%**
Fruits and vegetables	0.8%	0.4%	1.0%	0.3%	0.2%	**2.8%**
Meat	0.0%	0.0%	0.1%	0.2%	0.1%	**0.4%**
Milk	0.0%	0.0%	0.1%	0.5%	0.0%	**0.6%**
Oilseeds and pulses	2.1%	3.3%	0.7%	0.2%	0.1%	**6.4%**
Roots and tubers	0.3%	0.9%	0.2%	0.2%	0.0%	1.6%
Sub Saharan Africa	**3.2%**	**3.3%**	**1.8%**	**0.9%**	**0.3%**	**9.4%**
Cereals	1.0%	1.3%	0.5%	0.3%	0.1%	**3.3%**
Fish and seafood	0.0%	0.0%	0.0%	0.0%	0.0%	**0.1%**
Fruits and vegetables	0.2%	0.2%	0.3%	0.2%	0.0%	**0.9%**
Meat	0.0%	0.0%	0.0%	0.1%	0.0%	**0.1%**
Milk	0.0%	0.0%	0.0%	0.1%	0.0%	**0.1%**
Oilseeds and pulses	0.7%	0.4%	0.3%	0.1%	0.0%	**1.5%**
Roots and tubers	1.3%	1.4%	0.6%	0.2%	0.1%	3.5%
World	**26.0%**	**26.8%**	**17.8%**	**8.4%**	**21.1%**	**100.0%**
Cereals	12.1%	17.6%	10.2%	3.1%	14.8%	**57.7%**
Fish and seafood	0.0%	0.0%	0.3%	0.5%	0.3%	**1.1%**
Fruits and vegetables	3.2%	1.6%	2.0%	1.5%	1.8%	**10.1%**
Meat	0.0%	0.0%	1.3%	1.3%	1.9%	**4.4%**
Milk	0.0%	0.0%	0.3%	0.8%	0.9%	**2.1%**
Oilseeds and pulses	7.0%	4.5%	2.3%	0.5%	0.8%	**15.1%**
Roots and tubers	3.7%	3.2%	1.5%	0.7%	0.6%	**9.6%**

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c) Protein waste (g/p/day)

	Harvest	Post-harvest	Processing	Distribution	Consumer	Total
Europe inc Russia	**3.1**	**3.1**	**2.9**	**1.4**	**6.3**	**17.0**
Cereals	1.4	2.8	1.7	0.3	3.5	**9.7**
Fish and seafood	0.0	0.0	0.2	0.3	0.3	**0.9**
Fruits and vegetables	0.5	0.1	0.0	0.2	0.4	**1.3**
Meat	0.0	0.0	0.6	0.5	1.2	**2.3**
Milk	0.0	0.0	0.1	0.0	0.6	**0.8**
Oilseeds and pulses	0.1	0.0	0.1	0.0	0.1	**0.3**
Roots and tubers	0.6	0.2	0.2	0.1	0.2	**1.3**
Industrialised Asia	**1.3**	**3.2**	**2.6**	**1.8**	**4.4**	**13.3**
Cereals	0.6	3.0	1.4	0.2	2.3	**7.5**
Fish and seafood	0.0	0.0	0.3	0.6	0.4	**1.3**
Fruits and vegetables	0.6	0.5	0.1	0.4	0.7	**2.3**
Meat	0.0	0.0	0.5	0.5	0.6	**1.6**
Milk	0.0	0.0	0.0	0.0	0.2	**0.2**
Oilseeds and pulses	-0.7	-0.3	0.2	0.0	0.1	**-0.7**
Roots and tubers	0.3	0.1	0.1	0.1	0.1	**0.7**
Latin America	**9.2**	**3.2**	**3.1**	**2.0**	**2.5**	**20.0**
Cereals	2.2	1.4	1.4	0.5	1.3	**6.8**
Fish and seafood	0.0	0.0	0.2	0.2	0.1	**0.4**
Fruits and vegetables	0.7	0.3	0.3	0.1	0.1	**1.5**
Meat	0.0	0.0	0.6	0.6	0.7	**1.9**
Milk	0.0	0.0	0.1	0.4	0.2	**0.7**
Oilseeds and pulses	2.9	1.4	0.5	0.1	0.1	**5.0**
Roots and tubers	0.2	0.1	0.1	0.0	0.0	**0.4**
North Africa, West and Central Asia	**3.1**	**2.7**	**3.6**	**2.1**	**3.5**	**15.2**
Cereals	1.9	2.3	2.2	0.9	2.6	**9.9**
Fish and seafood	0.0	0.0	0.2	0.2	0.1	**0.4**
Fruits and vegetables	0.7	0.3	0.6	0.3	0.2	**2.1**
Meat	0.0	0.0	0.3	0.3	0.5	**1.1**
Milk	0.0	0.0	0.1	0.3	0.1	**0.5**
Oilseeds and pulses	-0.1	0.0	0.2	0.0	0.0	**0.2**
Roots and tubers	0.1	0.1	0.1	0.0	0.0	**0.3**
North America and Oceania	**13.3**	**2.9**	**3.8**	**1.8**	**10.1**	**31.9**
Cereals	2.8	2.7	2.2	0.4	5.0	**13.1**
Fish and seafood	0.0	0.0	0.2	0.3	0.9	**1.4**
Fruits and vegetables	0.4	0.1	0.0	0.3	0.6	**1.4**
Meat	0.0	0.0	0.9	0.7	1.8	**3.4**
Milk	0.0	0.0	0.1	0.0	1.4	**1.6**
Oilseeds and pulses	8.7	0.0	0.2	0.0	0.1	**9.1**
Roots and tubers	0.3	0.1	0.1	0.1	0.2	**0.8**
South and Southeast Asia	**2.4**	**2.2**	**1.6**	**1.2**	**0.7**	**8.1**
Cereals	1.2	1.4	0.5	0.3	0.4	**3.8**
Fish and seafood	0.0	0.0	0.2	0.3	0.0	**0.6**
Fruits and vegetables	0.3	0.2	0.4	0.1	0.1	**1.1**
Meat	0.0	0.0	0.1	0.1	0.1	**0.3**
Milk	0.0	0.0	0.1	0.3	0.0	**0.3**
Oilseeds and pulses	0.3	0.5	0.3	0.1	0.0	**1.2**
Roots and tubers	0.1	0.2	0.0	0.0	0.0	**0.3**
Sub Saharan Africa	**2.7**	**2.4**	**1.6**	**1.1**	**0.3**	**8.2**
Cereals	0.9	1.2	0.5	0.3	0.1	**3.0**
Fish and seafood	0.0	0.0	0.2	0.2	0.0	**0.4**
Fruits and vegetables	0.2	0.1	0.3	0.1	0.0	**0.7**
Meat	0.0	0.0	0.2	0.2	0.1	**0.4**
Milk	0.0	0.0	0.0	0.1	0.0	**0.1**
Oilseeds and pulses	0.9	0.5	0.3	0.1	0.0	**1.9**
Roots and tubers	0.5	0.6	0.2	0.1	0.0	**1.4**
World	**3.5**	**2.7**	**2.4**	**1.5**	**2.9**	**13.0**
Cereals	1.3	2.0	1.1	0.3	1.6	**6.3**
Fish and seafood	0.0	0.0	0.2	0.3	0.2	**0.8**
Fruits and vegetables	0.5	0.2	0.3	0.2	0.3	**1.5**
Meat	0.0	0.0	0.3	0.3	0.5	**1.2**
Milk	0.0	0.0	0.1	0.2	0.2	**0.4**
Oilseeds and pulses	0.8	0.3	0.2	0.1	0.1	**1.5**
Roots and tubers	0.3	0.2	0.1	0.0	0.1	**0.7**

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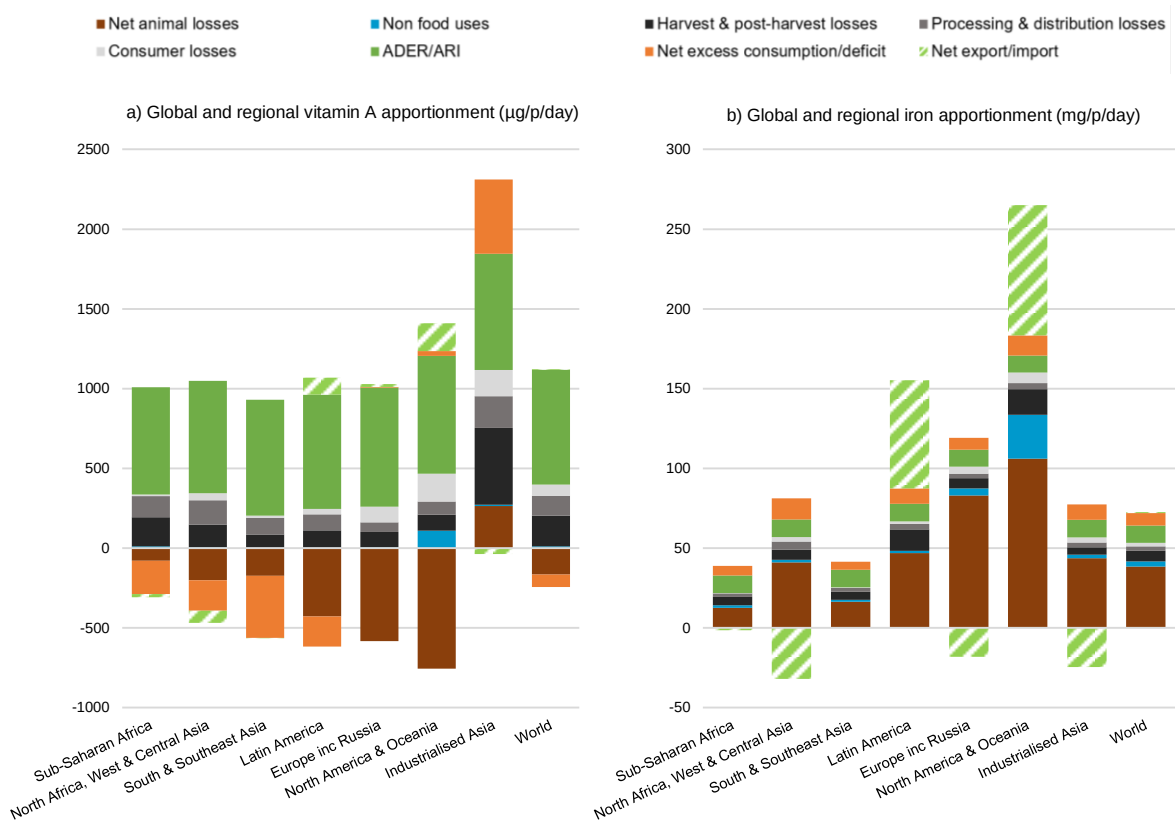
d) Protein waste (proportion of the world total waste)

	Harvest	Post-harvest	Processing	Distribution	Consumer	Total
Europe inc Russia	**2.5%**	**2.6%**	**2.4%**	**1.2%**	**5.2%**	**13.9%**
Cereals	1.2%	2.3%	1.4%	0.2%	2.9%	**8.0%**
Fish and seafood	0.0%	0.0%	0.2%	0.2%	0.3%	**0.7%**
Fruits and vegetables	0.4%	0.1%	0.0%	0.2%	0.3%	**1.1%**
Meat	0.0%	0.0%	0.5%	0.4%	1.0%	**1.9%**
Milk	0.0%	0.0%	0.1%	0.0%	0.5%	**0.6%**
Oilseeds and pulses	0.1%	0.0%	0.1%	0.0%	0.1%	**0.3%**
Roots and tubers	0.5%	0.2%	0.2%	0.1%	0.1%	**1.0%**
Industrialised Asia	**2.2%**	**5.4%**	**4.5%**	**3.1%**	**7.5%**	**22.7%**
Cereals	1.0%	5.0%	2.4%	0.4%	4.0%	**12.8%**
Fish and seafood	0.0%	0.0%	0.6%	1.0%	0.6%	**2.2%**
Fruits and vegetables	1.1%	0.8%	0.2%	0.7%	1.2%	**3.9%**
Meat	0.0%	0.0%	0.8%	0.9%	1.1%	**2.7%**
Milk	0.0%	0.0%	0.1%	0.0%	0.3%	**0.4%**
Oilseeds and pulses	-1.2%	-0.6%	0.3%	0.1%	0.2%	**-1.1%**
Roots and tubers	0.6%	0.2%	0.2%	0.1%	0.1%	**1.1%**
Latin America	**6.2%**	**2.2%**	**2.1%**	**1.4%**	**1.7%**	**13.6%**
Cereals	1.5%	0.9%	0.9%	0.4%	0.9%	**4.6%**
Fish and seafood	0.0%	0.0%	0.1%	0.1%	0.0%	**0.3%**
Fruits and vegetables	0.5%	0.2%	0.2%	0.1%	0.1%	**1.0%**
Meat	0.0%	0.0%	0.4%	0.4%	0.5%	**1.3%**
Milk	0.0%	0.0%	0.1%	0.3%	0.1%	**0.5%**
Oilseeds and pulses	2.0%	0.9%	0.3%	0.1%	0.1%	**3.4%**
Roots and tubers	0.1%	0.1%	0.0%	0.0%	0.0%	**0.3%**
North Africa, West and Central Asia	**1.5%**	**1.3%**	**1.8%**	**1.0%**	**1.7%**	**7.4%**
Cereals	0.9%	1.1%	1.1%	0.4%	1.3%	**4.8%**
Fish and seafood	0.0%	0.0%	0.1%	0.1%	0.0%	**0.2%**
Fruits and vegetables	0.3%	0.2%	0.3%	0.2%	0.1%	**1.0%**
Meat	0.0%	0.0%	0.2%	0.2%	0.2%	**0.5%**
Milk	0.0%	0.0%	0.0%	0.2%	0.0%	**0.2%**
Oilseeds and pulses	0.0%	0.0%	0.1%	0.0%	0.0%	**0.1%**
Roots and tubers	0.0%	0.0%	0.0%	0.0%	0.0%	**0.1%**
North America and Oceania	**5.6%**	**1.2%**	**1.6%**	**0.7%**	**4.3%**	**13.5%**
Cereals	1.2%	1.1%	0.9%	0.2%	2.1%	**5.5%**
Fish and seafood	0.0%	0.0%	0.1%	0.1%	0.4%	**0.6%**
Fruits and vegetables	0.2%	0.0%	0.0%	0.1%	0.2%	**0.6%**
Meat	0.0%	0.0%	0.4%	0.3%	0.8%	**1.4%**
Milk	0.0%	0.0%	0.0%	0.0%	0.6%	**0.7%**
Oilseeds and pulses	3.7%	0.0%	0.1%	0.0%	0.1%	**3.8%**
Roots and tubers	0.1%	0.0%	0.1%	0.0%	0.1%	**0.3%**
South and Southeast Asia	**6.4%**	**5.8%**	**4.2%**	**3.2%**	**1.7%**	**21.4%**
Cereals	3.2%	3.6%	1.3%	0.7%	1.1%	**9.9%**
Fish and seafood	0.0%	0.0%	0.6%	0.8%	0.1%	**1.5%**
Fruits and vegetables	0.9%	0.5%	1.1%	0.3%	0.2%	**3.0%**
Meat	0.0%	0.0%	0.3%	0.4%	0.2%	**0.9%**
Milk	0.0%	0.0%	0.1%	0.7%	0.1%	**0.9%**
Oilseeds and pulses	0.9%	1.4%	0.7%	0.2%	0.1%	**3.2%**
Roots and tubers	0.1%	0.4%	0.1%	0.1%	0.0%	0.8%
Sub Saharan Africa	**2.5%**	**2.2%**	**1.5%**	**1.0%**	**0.3%**	**7.6%**
Cereals	0.9%	1.1%	0.4%	0.2%	0.1%	**2.8%**
Fish and seafood	0.0%	0.0%	0.1%	0.2%	0.0%	**0.4%**
Fruits and vegetables	0.1%	0.1%	0.2%	0.1%	0.0%	**0.7%**
Meat	0.0%	0.0%	0.1%	0.2%	0.0%	**0.4%**
Milk	0.0%	0.0%	0.0%	0.1%	0.0%	**0.1%**
Oilseeds and pulses	0.8%	0.5%	0.3%	0.1%	0.0%	**1.7%**
Roots and tubers	0.5%	0.5%	0.2%	0.1%	0.0%	1.3%
World	**27.1%**	**20.8%**	**18.1%**	**11.7%**	**22.4%**	**100.0%**
Cereals	9.9%	15.2%	8.5%	2.6%	12.3%	**48.6%**
Fish and seafood	0.0%	0.0%	1.7%	2.6%	1.5%	**5.8%**
Fruits and vegetables	3.5%	1.8%	2.0%	1.7%	2.2%	**11.3%**
Meat	0.0%	0.0%	2.7%	2.7%	3.8%	**9.1%**
Milk	0.0%	0.0%	0.5%	1.4%	1.6%	**3.4%**
Oilseeds and pulses	6.3%	2.2%	1.9%	0.4%	0.6%	**11.4%**
Roots and tubers	1.9%	1.5%	0.8%	0.4%	0.4%	**5.0%**

S5. The apportionment of food vitamin A (a), iron (b) and zinc (c) at the global and regional scales between various end points



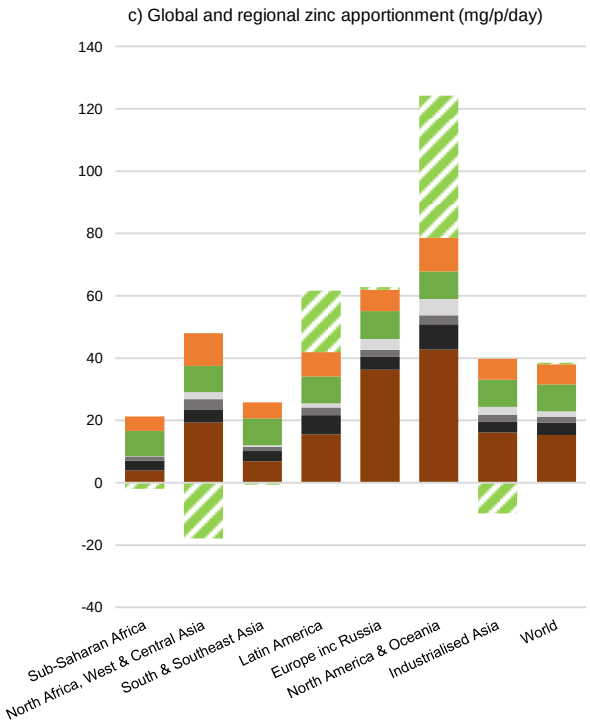


Figure S1: The apportionment of food vitamin A (a), iron (b) and zinc (c) at the global and regional scales between various end points. The bar height above zero represents the amount of food available in the region. This is divided into the categories shown in the key.

The ARI values are regionally adjusted. The orange segments show net overconsumption, or, in the case of Industrialised Asia, a small net deficit. Hashed segments show net exports (above zero) and net imports (below zero) which contribute to the total available shown above zero. These data are shown in S.I. Table 2.

145 *Table S2: The apportionment of food calories, protein, vitamin A, iron and zinc at the global and regional scales between*
146 *various end points. Data for energy and protein are visualised in Figure 2 (a) and (b), respectively.*
147

	Grown	Invested	Net export / import	Net animal loss	Non-food uses	Harvest and post-harvest losses	Processing and distribution losses	Consumer losses	ADER/ARI	Net excess consumption /deficit
Energy (kcal/p/day)										
Sub-Saharan Africa	3607	60	-494	374	299	671	275	31	2184	206
North Africa, West & Central Asia	3707	159	-2464	1448	411	552	484	296	2331	490
South & Southeast Asia	4268	80	301	263	427	623	226	66	2271	9
Latin America	9519	101	2308	1269	1348	987	439	226	2366	473
Europe inc Russia	8712	379	188	2643	993	666	375	567	2508	393
North America & Oceania	18766	230	4483	3813	4036	1081	507	899	2509	1209
Industrialised Asia	4463	83	-1273	1370	680	548	339	381	2455	-120
World	5935	126	73	1139	808	669	324	261	2353	183
Protein (g/p/day)										
Sub-Saharan Africa	88	2	-12	6	4	14	8	1	41	24
North Africa, West & Central Asia	120	6	-87	63	4	16	16	10	43	50
South & Southeast Asia	97	3	-7	13	3	13	8	2	45	19
Latin America	390	6	172	52	7	34	14	7	44	53
Europe inc Russia	262	13	-21	119	8	17	12	17	47	49
North America & Oceania	746	14	260	170	96	44	15	28	46	73
Industrialised Asia	128	3	-68	65	7	12	12	12	45	41
World	184	5	2.38	50	10	17	11	8	44	36
Vitamin A (µg/p/day)										
Sub-Saharan Africa	702.6	4.5	-20.9	-81.6	8.8	182.9	132.6	11.1	672.3	-207.1
North Africa, West & Central Asia	580.7	3.0	-75.5	-203.9	4.0	143.0	151.3	43.8	705.1	-190.0
South & Southeast Asia	364.8	2.1	-3.5	-175.6	1.1	82.1	104.4	14.5	727.8	-388.1
Latin America	450.4	2.7	105.6	-430.1	2.6	108.2	99.4	33.6	717.6	-189.1
Europe inc Russia	443.9	0.9	19.0	-584.9	3.0	96.7	61.2	97.6	747.2	3.1
North America & Oceania	656.8	4.4	174.4	-756.2	108.3	100.2	82.3	174.1	739.1	30.2
Industrialised Asia	2272.5	0.8	-39.0	263.2	7.4	482.4	198.1	164.9	727.8	466.9
World	878.0	2.2	3.7	-166.4	9.8	192.5	125.4	69.0	720.9	-79.2
Iron (mg/p/day)										
Sub-Saharan Africa	37.80	0.60	-1.55	12.50	1.52	5.32	2.16	0.24	10.94	6.06
North Africa, West & Central Asia	50.68	1.76	-32.09	40.97	1.60	6.39	4.93	2.89	10.97	13.25
South & Southeast Asia	42.02	0.73	-0.08	16.33	1.19	5.02	2.25	0.54	10.99	5.06
Latin America	157.40	2.26	67.79	46.70	1.37	13.46	3.42	1.60	11.06	9.75
Europe inc Russia	105.01	4.25	-18.31	82.94	4.29	6.44	2.93	4.33	10.61	7.52
North America & Oceania	269.59	4.63	81.76	105.91	27.59	15.97	3.85	6.68	10.64	12.56
Industrialised Asia	53.37	0.84	-24.73	43.59	2.11	4.68	2.93	3.32	10.99	9.65
World	74.05	1.53	0.70	38.32	3.26	6.56	2.83	2.11	10.93	7.82
Zinc (mg/p/day)										
Sub-Saharan Africa	20.71	0.40	-1.94	3.93	0.97	3.15	1.33	0.16	8.07	4.65
North Africa, West & Central Asia	32.72	1.40	-17.83	19.31	1.13	4.17	3.34	2.22	8.45	10.54
South & Southeast Asia	26.66	0.63	-0.58	6.90	0.87	3.28	1.37	0.42	8.71	5.05
Latin America	67.40	0.98	19.67	15.53	4.81	6.11	2.50	1.34	8.61	7.84
Europe inc Russia	68.15	3.22	0.78	36.24	2.20	4.18	2.23	3.48	8.91	6.93
North America & Oceania	148.89	2.32	45.58	42.71	22.39	8.11	2.89	5.24	8.84	10.81
Industrialised Asia	32.33	0.66	-9.87	16.10	1.75	3.39	2.25	2.62	8.71	6.72
World	42.37	1.06	0.55	15.28	2.77	3.96	1.96	1.67	8.63	6.49

S6. Is the current global food supply compatible with a healthy diet?

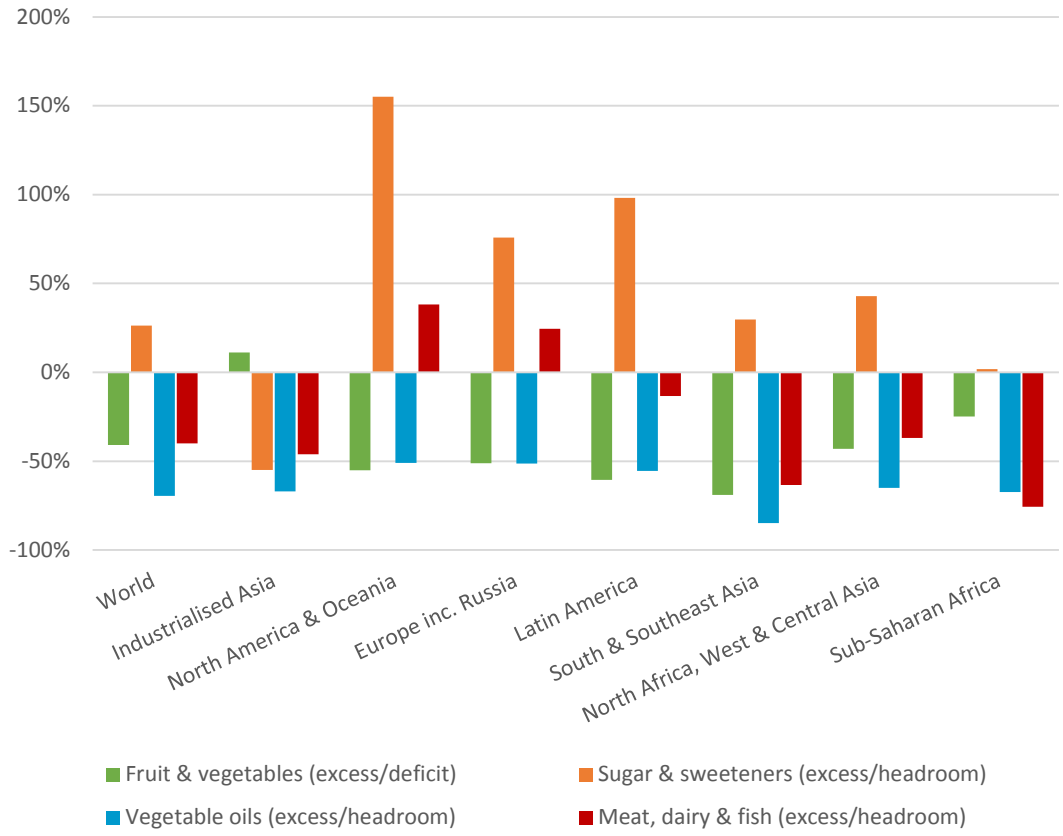


Figure S2: Current (2013) global and regional consumption of four food types as a percentage of recommended maximum and minimum healthy dietary limits.

S7. Food supply under future hypothetical scenarios

Table S3: Distribution of energy and protein between seven end-points for the current system (A_{2013}) and 9 scenarios in kcal/p/d. See the caption to Figure 3 for details.

Energy (kcal/p/d)	**A_{2013}**	**A_{2050}**	**B_{2013}**	**B_{2050}**	**C_{2013}**	**C_{2050}**	**D_{2013}**	**D_{2050}**	**E_{2050}**	**F_{2050}**
Non-food uses	808	0	2359	927	2312	1092	2349	1023	0	0
Waste	1327	1133	1327	1133	0	0	651	554	0	0
Animal losses (grass, pasture & stover)	3404	2514	3404	2514	3404	2514	3404	2514	2514	2514
Animal losses (feed)	1552	1146	0	0	1552	1146	776	573	2441	3575
Invested	126	93	126	93	126	93	126	93	97	122
Net excess consumption	178	0	178	178	0	0	89	89	0	0
Vegetal required & eaten	1759	1874	1945	2052	1759	1914	1852	1983	1759	1623
Meat & dairy eaten	594	439	408	301	594	439	501	370	594	730
Vegetal deficiency	0	40	0	0	0	0	0	0	0	0
Protein (g/p/d)										
Non-food uses	10	0	74	29	84	51	81	41	0	0
Waste	38	33	38	33	0	0	18	15	0	0
Animal losses (grass, pasture & stover)	37	27	37	27	37	27	37	27	27	27
Animal losses (feed)	64	47	0	0	64	47	32	24	74	97
Invested	5	4	5	4	5	4	5	4	4	5
Net excess consumption	36	18	36	36	0	0	18	18	30	42
Vegetal required & eaten	6	16	30	34	6	16	18	25	6	0
Meat & dairy eaten	38	28	14	10	38	28	26	19	38	47
Vegetal deficiency	0	0	0	0	0	0	0	0	0	0

END