**Supplementary Information for:**

**Rebound effects could offset more than half of avoided food waste and loss**

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**Table S1 | Price elasticities of demand.** Range of estimates for elasticities of demand for different income regions from Green et al (2013). While Green et al analyzed 10 food groups, our study included equivalents for Fruits and Vegetables, Meat, Dairy, Cereals, and Fats and Oils only.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Low Income** | | | **Middle Income** | | | **High Income** | | |
|  | **n = 1412** | | | **n = 827** | | | **n = 1124** | | |
| **Food Groups** | *Low* | *Average* | *High* | *Low* | *Average* | *High* | *Low* | *Average* | *High* |
| Fruits & Vegetables | -0.77 | -0.72 | -0.66 | -0.71 | -0.65 | -0.59 | -0.59 | -0.53 | -0.48 |
| Meat | -0.83 | -0.78 | -0.73 | -0.78 | -0.72 | -0.66 | -0.66 | -0.60 | -0.54 |
| Fish | -0.85 | -0.80 | -0.74 | -0.79 | -0.73 | -0.67 | -0.67 | -0.61 | -0.55 |
| Dairy | -0.84 | -0.78 | -0.73 | -0.78 | -0.72 | -0.66 | -0.66 | -0.60 | -0.54 |
| Cereals | -0.66 | -0.61 | -0.56 | -0.61 | -0.55 | -0.49 | -0.48 | -0.43 | -0.36 |
| Fats and oils | -0.65 | -0.60 | -0.54 | -0.60 | -0.54 | -0.47 | -0.48 | -0.42 | -0.35 |

**Table S2 | Food type key.** This key translate correlates the FAO food types to the nearest equivalent of food types used by Green et al 2013.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Green et al 2013** | | **FAO Food Types** | | | | **Green Equivalency** | | |
| 1 | Fruits & Vegetables | 1 | Cereals | | | 6 | | |
| 2 | Meat | 2 | Fruits and Vegetables | | | 1 | | |
| 3 | Fish | 3 | Meat | | | 2 | | |
| 4 | Dairy | 4 | Milk | | | 4 | | |
| 5 | Eggs | 5 | Oilcrops and Pulses | | | 7 | | |
| 6 | Cereals | 6 | Roots and Tubers | | | 6 | | |
| 7 | Fats & Oils |
| 8 | Sweets, confectionary, & sweetened beverages |  |  |  |  |  |  |  |
| 9 | Other |  |  |  |  |  |  |  |
| 10 | All food groups combined |  |  |  |  |  |  |  |

**Table S3 | Region-income-group key.** This key determines SDG regions of interest as high, middle, or low income as determined by Green et al 2013 and the World Bank.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Green et al 2013** | | **SDG Region** | | **Green Equivalency** | |
| 1 | Low | 1 | Australia and New Zealand | 3 | High |
| 2 | Middle | 2 | Central and Southern Asia | 2 | Middle |
| 3 | High | 3 | Eastern and South-Eastern Asia | 2 | Middle |
|  |  | 4 | Latin America and the Caribbean | 2 | Middle |
|  |  | 5 | Northern America and Europe | 3 | High |
|  |  | 6 | Oceania (excluding Australia and New Zealand) | 2 | Middle |
|  |  | 7 | Sub-Saharan Africa | 1 | Low |
|  |  | 8 | Western Asia and Northern Africa | 2 | Middle |

**Table S4 | Price elasticities of supply .** Price elasticities of supply as determined by the USDA Economic Research Service (ERS) SWOPSIM Model Appendix Table 772.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Region/Food Type* | *Australia and New Zealand* | *Central and Southern Asia* | *Eastern and South-Eastern Asia* | *Latin America and the Caribbean* | *Northern America and Europe* | *Oceania (excluding Australia and New Zealand)* | *Sub-Saharan Africa* | *Western Asia and Northern Africa* |
| *Cereals* | 0.35 | 0.29 | 0.29 | 0.29 | 0.31 | 0.29 | 0.29 | 0.29 |
| *Fruits and Vegetables* | 0.35 | 0.29 | 0.29 | 0.29 | 0.31 | 0.29 | 0.29 | 0.29 |
| *Meat* | 0.60 | 0.49 | 0.49 | 0.49 | 0.63 | 0.49 | 0.49 | 0.49 |
| *Milk* | 0.60 | 0.49 | 0.49 | 0.49 | 0.63 | 0.49 | 0.49 | 0.49 |
| *Oilcrops and Pulses* | 0.35 | 0.29 | 0.29 | 0.29 | 0.31 | 0.29 | 0.29 | 0.29 |
| *Roots and Tubers* | 0.35 | 0.29 | 0.29 | 0.29 | 0.31 | 0.29 | 0.29 | 0.29 |

**Tables S5 | Aggregated food supply for human consumption for all regions and food types.** Food supply values calculated using Equation 3b for all region and food type combinations using FAOSTAT data from the year 2019. For a more detailed aggregation process, see SI Data 1.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Food Supply (Mt)** | | | | | | |
| *Food Type / Region* | *Cereals* | *Fruits and Vegetables* | *Meat* | *Milk* | *Oilcrops and Pulses* | *Roots and Tubers* |
| *Australia and New Zealand* | 2.39E+07 | 7.22E+06 | 3.45E+06 | 4.68E+07 | 3.07E+06 | 1.90E+06 |
| *Central and Southern Asia* | 8.49E+08 | 3.36E+08 | 1.42E+07 | 2.62E+08 | 1.11E+08 | 9.14E+07 |
| *Eastern and South-Eastern Asia* | 1.43E+09 | 9.99E+08 | 1.24E+08 | 6.66E+07 | 6.13E+08 | 2.57E+08 |
| *Latin America and the Caribbean* | 3.49E+08 | 1.50E+08 | 4.30E+07 | 1.02E+08 | 1.60E+08 | 5.43E+07 |
| *Northern America and Europe* | 1.06E+09 | 2.86E+08 | 1.28E+08 | 5.68E+08 | 2.03E+08 | 1.39E+08 |
| *Oceania (excluding Australia and New Zealand)* | 1.37E+06 | 3.59E+06 | 7.24E+05 | 1.05E+05 | 4.96E+06 | 2.54E+06 |
| *Sub-Saharan Africa* | 3.11E+08 | 1.34E+08 | 1.09E+07 | 3.15E+07 | 7.54E+07 | 3.52E+08 |
| *Western Asia and Northern Africa* | 2.80E+08 | 1.48E+08 | 1.33E+07 | 7.39E+07 | 3.52E+07 | 2.46E+07 |

**Tables S6 | Consumer food price indices by region.** Consumer food price indices from 2019 provided by FAOSTAT.

|  |  |
| --- | --- |
| **Region** | **Consumer Price, Food Indices** |
| Australia and New Zealand | 103.79 |
| Central and Southern Asia | 128.24 |
| Eastern and South-Eastern Asia | 110.37 |
| Latin America and the Caribbean | 139.22 |
| Northern America and Europe | 104.65 |
| Oceania (excluding Australia and New Zealand) | 106.89 |
| Sub-Saharan Africa | 151.64 |
| Western Asia and Northern Africa | 145.98 |

**Tables S7 | Food loss and waste percentages by region.** Food loss is determined using officially reported data from FAOSTAT supply utilization accounts. For food waste, we sum food waste across all regions from the 2021 Food Waste Index (FWI) report. Note that because the UNEP report does not distinguish between differences in in food types, we assume the same fraction of food wasted for each food type. For a more detailed calculation and assumptions, see SI Data 1.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Food Loss (tonnes)** | | | | | | |
| *Food Type / Region* | *Cereals* | *Fruits and Vegetables* | *Meat* | *Milk* | *Oilcrops and Pulses* | *Roots and Tubers* |
| *Australia and New Zealand* | 32578 | 318195 | 0 | 16575 | 6725 | 31873 |
| *Central and Southern Asia* | 7439096 | 26529304 | 32970 | 4101106 | 1406225 | 10163465 |
| *Eastern and South-Eastern Asia* | 9231692 | 70753491 | 523688 | 1437025 | 1376443 | 6279558 |
| *Latin America and the Caribbean* | 4066350 | 12653765 | 486422 | 2837753 | 416845 | 2515427 |
| *Northern America and Europe* | 3096841 | 12384451 | 250263 | 226253 | 292025 | 5691997 |
| *Oceania (excluding Australia and New Zealand)* | 1738 | 264635 | 580 | 1327 | 22655 | 161229 |
| *Sub-Saharan Africa* | 4780094 | 11427810 | 36779 | 1036772 | 1602835 | 12904918 |
| *Western Asia and Northern Africa* | 3178059 | 11719339 | 64343 | 1390285 | 284740 | 2522037 |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Food Waste (tonnes)** | | | | | | |
| *Food Type / Region* | *Cereals* | *Fruits and Vegetables* | *Meat* | *Milk* | *Oilcrops and Pulses* | *Roots and Tubers* |
| *Australia and New Zealand* | 428599 | 793381 | 532100 | 651574 | 32253 | 267017 |
| *Central and Southern Asia* | 57549974 | 56798905 | 2778599 | 37637199 | 7574131 | 12483126 |
| *Eastern and South-Eastern Asia* | 59714024 | 140328951 | 20163570 | 7772545 | 5668945 | 20769739 |
| *Latin America and the Caribbean* | 13217756 | 19702451 | 7718198 | 9731096 | 2048717 | 5353139 |
| *Northern America and Europe* | 17110314 | 31728966 | 13326441 | 20292089 | 1111377 | 11203361 |
| *Oceania (excluding Australia and New Zealand)* | 152570 | 649778 | 148228 | 15437 | 120362 | 407871 |
| *Sub-Saharan Africa* | 40416885 | 37871788 | 3734401 | 7373014 | 6415517 | 51013243 |
| *Western Asia and Northern Africa* | 19479217 | 26770831 | 3004221 | 8968743 | 1691539 | 3977919 |

**Tables S8a-d | Aggregated results for all regions and food types.** Median rebound percent (R) (a), consumption increase (∆C) (b), waste avoided (∆W) (c), and loss avoided (∆L) (d) for all region and food type combinations.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 1. **Rebound Percent (%)** | | | | | | | |
| *Food Type / Region* | *Cereals* | *Fruits and Vegetables* | *Meat* | *Milk* | *Oilcrops and Pulses* | *Roots and Tubers* | *Fish and Seafood* |
| *Australia and New Zealand* | 0.58 | 0.64 | 0.53 | 0.53 | 0.58 | 0.58 | 0.58 |
| *Central and Southern Asia* | 0.64 | 0.69 | 0.57 | 0.58 | 0.64 | 0.65 | 0.64 |
| *Eastern and South-Eastern Asia* | 0.64 | 0.68 | 0.57 | 0.57 | 0.64 | 0.64 | 0.64 |
| *Latin America and the Caribbean* | 0.65 | 0.69 | 0.57 | 0.58 | 0.64 | 0.65 | 0.65 |
| *Northern America and Europe* | 0.58 | 0.64 | 0.53 | 0.53 | 0.58 | 0.58 | 0.58 |
| *Oceania (excluding Australia and New Zealand)* | 0.64 | 0.69 | 0.57 | 0.59 | 0.64 | 0.65 | 0.64 |
| *Sub-Saharan Africa* | 0.68 | 0.71 | 0.60 | 0.61 | 0.67 | 0.68 | 0.68 |
| *Western Asia and Northern Africa* | 0.65 | 0.69 | 0.58 | 0.58 | 0.64 | 0.65 | 0.65 |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 1. **Consumption Increase (Mt)** | | | | | | | |
| *Food Type / Region* | *Cereals* | *Fruits and Vegetables* | *Meat* | *Milk* | *Oilcrops and Pulses* | *Roots and Tubers* | *Fish and Seafood* |
| *Australia and New Zealand* | -8.02E-02 | -4.14E-02 | -1.26E-01 | -1.49E-01 | -4.84E-03 | -4.65E-02 | -8.02E-02 |
| *Central and Southern Asia* | -7.84E+00 | 1.45E-01 | -5.82E-01 | -6.81E+00 | -9.19E-01 | 1.14E+00 | -7.84E+00 |
| *Eastern and South-Eastern Asia* | -7.70E+00 | 1.95E+00 | -4.16E+00 | -1.24E+00 | -5.85E-01 | -1.67E+00 | -7.70E+00 |
| *Latin America and the Caribbean* | -1.03E+00 | 1.26E+00 | -1.50E+00 | -1.24E+00 | -2.32E-01 | -1.30E-01 | -1.03E+00 |
| *Northern America and Europe* | -2.69E+00 | -1.82E+00 | -3.09E+00 | -4.75E+00 | -1.51E-01 | -6.73E-01 | -2.69E+00 |
| *Oceania (excluding Australia and New Zealand)* | -2.66E-02 | -1.15E-02 | -3.13E-02 | -2.79E-03 | -1.44E-02 | -1.95E-02 | -2.66E-02 |
| *Sub-Saharan Africa* | -4.92E+00 | -1.35E+00 | -7.27E-01 | -1.14E+00 | -5.07E-01 | -3.81E+00 | -4.92E+00 |
| *Western Asia and Northern Africa* | -2.41E+00 | -1.54E-01 | -6.11E-01 | -1.49E+00 | -2.12E-01 | 1.25E-01 | -2.41E+00 |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 1. **Waste Avoided (Mt)** | | | | | | | |
| *Food Type / Region* | *Cereals* | *Fruits and Vegetables* | *Meat* | *Milk* | *Oilcrops and Pulses* | *Roots and Tubers* | *Fish and Seafood* |
| *Australia and New Zealand* | 2.14E-01 | 3.97E-01 | 2.66E-01 | 3.26E-01 | 1.61E-02 | 1.34E-01 | 2.14E-01 |
| *Central and Southern Asia* | 2.88E+01 | 2.84E+01 | 1.39E+00 | 1.88E+01 | 3.79E+00 | 6.24E+00 | 2.88E+01 |
| *Eastern and South-Eastern Asia* | 2.99E+01 | 7.02E+01 | 1.01E+01 | 3.89E+00 | 2.83E+00 | 1.04E+01 | 2.99E+01 |
| *Latin America and the Caribbean* | 6.61E+00 | 9.85E+00 | 3.86E+00 | 4.87E+00 | 1.02E+00 | 2.68E+00 | 6.61E+00 |
| *Northern America and Europe* | 8.56E+00 | 1.59E+01 | 6.66E+00 | 1.01E+01 | 5.56E-01 | 5.60E+00 | 8.56E+00 |
| *Oceania (excluding Australia and New Zealand)* | 7.63E-02 | 3.25E-01 | 7.41E-02 | 7.72E-03 | 6.02E-02 | 2.04E-01 | 7.63E-02 |
| *Sub-Saharan Africa* | 2.02E+01 | 1.89E+01 | 1.87E+00 | 3.69E+00 | 3.21E+00 | 2.55E+01 | 2.02E+01 |
| *Western Asia and Northern Africa* | 9.74E+00 | 1.34E+01 | 1.50E+00 | 4.48E+00 | 8.46E-01 | 1.99E+00 | 9.74E+00 |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 1. **Loss Avoided (Mt)** | | | | | | | |
| *Food Type / Region* | *Cereals* | *Fruits and Vegetables* | *Meat* | *Milk* | *Oilcrops and Pulses* | *Roots and Tubers* | *Fish and Seafood* |
| *Australia and New Zealand* | 1.63E-02 | 1.59E-01 | 0.00E+00 | 8.29E-03 | 3.36E-03 | 1.59E-02 | 1.63E-02 |
| *Central and Southern Asia* | 3.72E+00 | 1.33E+01 | 1.65E-02 | 2.05E+00 | 7.03E-01 | 5.08E+00 | 3.72E+00 |
| *Eastern and South-Eastern Asia* | 4.62E+00 | 3.54E+01 | 2.62E-01 | 7.19E-01 | 6.88E-01 | 3.14E+00 | 4.62E+00 |
| *Latin America and the Caribbean* | 2.03E+00 | 6.33E+00 | 2.43E-01 | 1.42E+00 | 2.08E-01 | 1.26E+00 | 2.03E+00 |
| *Northern America and Europe* | 1.55E+00 | 6.19E+00 | 1.25E-01 | 1.13E-01 | 1.46E-01 | 2.85E+00 | 1.55E+00 |
| *Oceania (excluding Australia and New Zealand)* | 8.69E-04 | 1.32E-01 | 2.90E-04 | 6.64E-04 | 1.13E-02 | 8.06E-02 | 8.69E-04 |
| *Sub-Saharan Africa* | 2.39E+00 | 5.71E+00 | 1.84E-02 | 5.18E-01 | 8.01E-01 | 6.45E+00 | 2.39E+00 |
| *Western Asia and Northern Africa* | 1.59E+00 | 5.86E+00 | 3.22E-02 | 6.95E-01 | 1.42E-01 | 1.26E+00 | 1.59E+00 |

**Table S9 | Environmental impact factor key.** Equivalents for FAO food types analyzed and food groups for categories with impact factors in the 2019 FAO State of Food and Agriculture (SOFA) Report. Note that we create a 5th impact factor type by using a weighted food supply average of categories 1 and 4 from the 2019 FAO SOFA Report to more accurately reflect the impact of Oilcrops and Pulses (column 2).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **2019 SOFA Report** | | **FAO Food Type** | | **Key** |
| 1 | Cereals and Pulses | 1 | *Cereals* | *1* |
| 2 | Fruits and Vegetables | 2 | *Fruits and Vegetables* | *2* |
| 3 | Meat and Animal Products | 3 | *Meat* | *3* |
| 4 | Roots, Tubers, and Oilbearing Crops | 4 | *Milk* | *3* |
|  |  | 5 | *Oilcrops and Pulses* | *5\** |
|  |  | 6 | *Roots and Tubers* | *4* |
|  |  | 7 | *Fish and Seafood* | *3* |

**Table S10 | Environmental impact factors.** 2019 State of Food and Agriculture impact factors for food loss and waste. We create a production-weighted average to represent Oilseeds and Pulses (column 5) for ease of analysis among food types (see Table S9 for equivalencies).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Carbon Impact Factor (Tonne of CO2 eqv/Tonne of food lost)** | | | | | |
| Food Type / SDG Region | Cereals and Pulses | Fruits and Vegetables | Meat and Animal Products | Roots, Tubers, and Oilbearing Crops | Average Oil/Pulses |
| Australia and New Zealand | 1.6 | 1.8 | 1.4 | 1.6 | 1.6 |
| Central and Southern Asia | 2.2 | 1.1 | 2.3 | 1.0 | 1.8 |
| Eastern and South-Eastern Asia | 2.6 | 1.0 | 5.6 | 1.0 | 1.2 |
| Latin America and the Caribbean | 1.7 | 1.1 | 4.4 | 1.3 | 1.5 |
| Northern America and Europe | 1.5 | 1.5 | 1.6 | 0.7 | 1.1 |
| Oceania (excluding Australia and New Zealand) | 2.3 | 1.1 | 3.6 | 2.3 | 2.3 |
| Sub-Saharan Africa | 1.9 | 0.5 | 2.3 | 0.5 | 1.4 |
| Western Asia and Northern Africa | 0.5 | 1.0 | 4.2 | 1.1 | 0.8 |
|  |  |  |  |  |  |
| **Water Impact Factor (m3 /tonne of food lost)** | | | | | |
| Food Type/ Region | Cereals and Pulses | Fruits and Vegetables | Meat and Animal Products | Roots, Tubers, and Oilbearing Crops | Average Oil/Pulses |
| Australia and New Zealand | 57.3 | 212.9 | 82.0 | 96.7 | 85.0 |
| Central and Southern Asia | 609.1 | 266.7 | 564.6 | 741.8 | 656.2 |
| Eastern and South-Eastern Asia | 130.0 | 301.8 | 181.6 | 17.9 | 32.6 |
| Latin America and the Caribbean | 146.9 | 271.8 | 168.1 | 28.0 | 100.1 |
| Northern America and Europe | 64.3 | 242.3 | 65.2 | 39.7 | 50.7 |
| Oceania (excluding Australia and New Zealand) | 354.3 | 301.8 | 174.7 | 14.0 | 24.5 |
| Sub-Saharan Africa | 146.7 | 239.9 | 161.5 | 147.9 | 147.1 |
| Western Asia and Northern Africa | 538.0 | 226.8 | 977.3 | 624.1 | 581.0 |
|  |  |  |  |  |  |
| **Land Impact Factor (ha/tonne of food lost)** | | | | | |
| Food Type/Region | Cereals and Pulses | Fruits and Vegetables | Meat and Animal Products | Roots, Tubers, and Oilbearing Crops | Average Oil/Pulses |
| Australia and New Zealand | 0.8 | 0.1 | 2.5 | 0.0 | 0.2 |
| Central and Southern Asia | 0.4 | 0.1 | 12.6 | 0.2 | 0.3 |
| Eastern and South-Eastern Asia | 0.3 | 0.1 | 11.8 | 0.2 | 0.2 |
| Latin America and the Caribbean | 0.6 | 0.1 | 4.0 | 0.2 | 0.4 |
| Northern America and Europe | 0.3 | 0.1 | 1.2 | 0.1 | 0.2 |
| Oceania (excluding Australia and New Zealand) | 0.5 | 0.1 | 4.5 | 0.3 | 0.3 |
| Sub-Saharan Africa | 0.9 | 0.1 | 17.0 | 0.6 | 0.8 |
| Western Asia and Northern Africa | 0.9 | 0.1 | 29.1 | 0.2 | 0.6 |

**Table S11 | Results for environmental impacts.** Global quantities for possible reductions (column 1) and the actual reduction (column 2) in environmental impacts due to rebound effects of avoided food waste and loss. Column 3 represents the percent offset due to rebound effects.

|  |  |  |  |
| --- | --- | --- | --- |
| **Environmental Impact** | **Possible Reduction** | **Actual Reduction** | **Offset (%)** |
| Emissions (Mt CO2 eqv) | 747.08 | 274.25 | 63 |
| Water (m3) | 1.25\* 1011 | 4.34\* 1010 | 65 |
| Land (ha) | 7.29 \* 108 | 2.99 \* 108 | 60 |