**IPBES Methods**

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# POLLINATION CONTRIBUTION TO HUMAN NUTRITION

Pollination service was considered in terms of pollinator-dependent nutrient production, and the dependence of that production on natural habitat around farmland. This nutrition production provided by wild pollinators was translated to potential number of people fed based on dietary requirements.

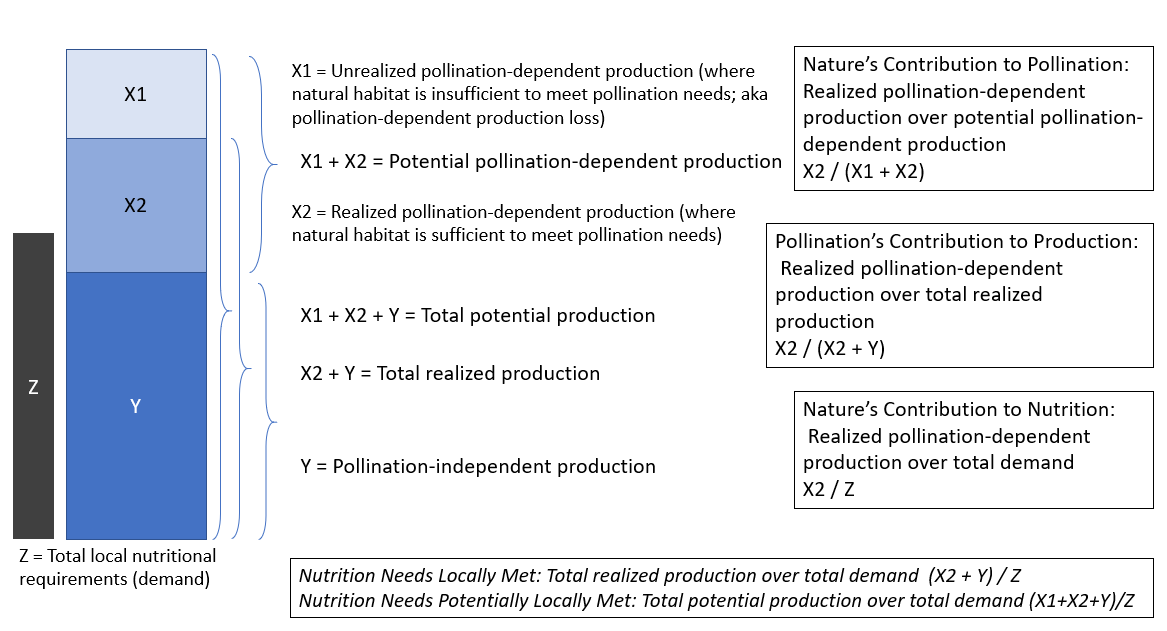
## Pollination sufficiency

### Overview

Pollination sufficiency was calculated based on the area of pollinator habitat around farmland. Agricultural pixels with >30% natural habitat in the 2 km area surrounding the farm were designated as receiving sufficient pollination for pollinator-dependent yields.

The analysis was run on landcover data from GLOBIO:

* 1850 historical scenario: Globio4\_landuse\_10sec\_1850.tif
* 1900 historical scenario: Globio4\_landuse\_10sec\_1900.tif
* 1910 historical scenario: Globio4\_landuse\_10sec\_1910.tif
* 1945 historical scenario: Globio4\_landuse\_10sec\_1945.tif
* 1980 historical scenario: Globio4\_landuse\_10sec\_1980.tif
* 2015 historical/current scenario: Globio4\_landuse\_10sec\_2015.tif
* 2050 SSP1 scenario: GLOBIO4\_LU\_10sec\_2050\_SSP1\_RCP26.tif
* 2050 SSP3 scenario: GLOBIO4\_LU\_10sec\_2050\_SSP3\_RCP70.tif
* 2050 SPP5 scenario: GLOBIO4\_LU\_10sec\_2050\_SSP5\_RCP85.tif



### Pollinator habitat

Pollinator habitat was defined as any natural land covers, as defined in Table X (GLOBIO land-cover classes 6, secondary vegetation, and 50-180, various types of primary vegetation). To test sensitivity to this definition we included "semi-natural" habitats (GLOBIO land-cover classes 3, 4, and 5; pasture, rangeland and forestry, respectively) in addition to "natural", and repeated all analyses with semi-natural plus natural habitats, but this did not substantially alter the results so we do not include it in our final analysis or code base.

### Proportional area

The proportional area of natural within 2 km was calculated for every pixel of agricultural land (GLOBIO land-cover classes 2, 230, 231, and 232) at 10 arc seconds (~300 m) resolution. This 2 km scale represents the distance most commonly found to be predictive of pollination services (Kennedy et al. 2013)[[1]](#footnote-1).

### Sufficiency threshold

A threshold of 0.3 was set to evaluate whether there was sufficient pollinator habitat in the 2 km around farmland to provide pollination services, based on Kremen et al.’s (2005)[[2]](#footnote-2) estimate of the area requirements for achieving full pollination. This produced a map of wild pollination sufficiency where every agricultural pixel was designated in a binary fashion: 0 if proportional area of habitat was less than 0.3; 1 if greater than 0.3. Maps of pollination sufficiency can be found at (permanent link to output), outputs “poll\_suff\_...” below.

## Pollination-dependent nutrient production

### Overview

Pollination-dependence of crops, crop yields, and crop micronutrient content were combined in an analysis to calculate pollination-dependent nutrient production, following Chaplin-Kramer et al. (2012)[[3]](#footnote-3).

### Pollination dependency

Crop pollination dependency was determined for 115 crops (permanent link to table). Dependency was defined as the percent by which yields are reduced for each crop with inadequate pollination (ranging from 0-95%), according to Klein et al. (2007)[[4]](#footnote-4). Cropproduction estimates calculated below production pixel

### Crop production

Spatially-explicit global crop yields (tons/ha) and the harvested area as a proportion of each grid cell at 5 arc min (~10 km) were taken from Monfreda et al. (2008) for 115 crops (<https://storage.cloud.google.com/ecoshard-root/ipbes/monfreda_2008_observed_yield_md5_54c6b8e564973739ba75c8e54ac6f051.zip>). Each crop was multiplied by its proportional area to derive a grid-level crop yield that could be scaled to any pixel size and multiplied by the area of the pixel to estimate the pixel level production. Thus, the grid-level crop yield (proportional area \* tons / ha) for a particular 5 arc min grid cell was applied to every 10 arc sec agricultural pixel that fell within that 5 arc min grid cell, and then multiplied by the area of the 10 arc sec pixel. While not a realistic portrayal of actual production of every crop at that 10 arc sec resolution, this essentially weights pollination dependency and nutrient production by current crop distributions, assuming those trends continue into the future.

### Crop nutrient content

Crop content of critical macro and micronutrients (KJ energy/100 g, IU Vitamin A/ 100 g and mcg Folate/100g) for the 115 crops were taken from [USDA](http://ndb.nal.usda.gov/) (2011)[[5]](#footnote-5). The USDA (2011) data also provided estimated refuse of the food item (e.g., peels, seeds). Total crop production and pollination-dependent crop production were reduced by this refuse percent and then multiplied by nutrient content, and summed across all crops to derive total potential nutrient production and pollination-dependent potential nutrient production (KJ, IU Vitamin A, mcg Folate) for each nutrient at 10 arc sec. The full table used in this analysis can be found at (permanent link to table).

## Nutrition provided by wild pollinators

### Overview

Nutrition provided by wild pollinators on each pixel of agricultural land was calculated according to pollination habitat sufficiency and the pollination-dependent nutrient yields.

### Nutrition production by wild pollinators

Pollinator-dependent nutrient production for every agricultural pixel in the GLOBIO land-use map at 10 arc seconds wasmultiplied by wild pollination sufficiency (a factor between 0 and 1, where 1 indicates >30% natural habitat in the 2km around cropland, and a value from 0 to 1 indicates the proportion from 0 to 30%) to report realized pollination-dependent nutrient production in each pixel. We call this “realized” to distinguish from the “potential” pollination dependence, which is the proportion that yields are reduced if not adequately pollinated. Whether that dependent yield is actually produced is determined by whether there is sufficient natural habitat around the agricultural pixel in question to provide wild pollinators and hence adequate pollination to crops. The difference between realized and potential production is the “unrealized” pollination-dependent production. Maps of realized, unrealized, and potential pollination-dependent nutrient production for each nutrient in each scenario can be found at (permanent link to output), outputs XXXX below.

### Total realized nutrition production

Total realized nutrition production was then calculated by subtracting unrealized pollination-dependent production from total potential production. Maps of total potential and realized nutrient production for each nutrient in each scenario can be found at (permanent link to output), outputs XXXX below.

### Contribution of nature to pollination and contribution of wild pollination to overall nutrition production

We consider two different metrics of “nature’s contribution” to pollination or nutrition production across all three micronutrients. The first is nature’s contribution to pollination, which is the ratio of the realized pollination-dependent production (the pollination-dependent production for which pollination needs are met, according to the habitat around farmland) to the potential pollination-dependent production (the full amount of production that is dependent on pollination, regardless of whether pollination needs are met). The second is pollination’s contribution to nutrition production, which is the ratio of the realized pollination-dependent production to the realized total production (which includes both realized pollination-dependent production and pollination-independent production).

Maps of these contribution for each nutrient in each scenario, along with total production of each nutrient, can be found at (permanent link to output), outputs XXXXX below. We also take the average contribution to pollination and to nutrition production across all the nutrients as summary metrics.

## Local nutritional adequacy

### Overview

Macro- and micronutrient requirements was calculated according to recommended dietary intake levels of different demographics. The nutrient production by wild pollinators was then scaled to nutrient requirements to represent the potential number of people fed.

### Mapping demographics and nutritional requirements

We used the age and sex dataset from Gridded Population of the World version 4 (GPW4)[[6]](#footnote-6) to map current demographics. For scenarios, we held the relative values of the different age groups and sexes constant in each pixel, and multiplied by the change in population. We then multiplied the population of each demographic group by its per capita annual requirements for each nutrient, described below. We summed these dietary requirements across all demographic groups to produce maps of total dietary requirements for each nutrient for each scenario (permanent link to output), outputs “nut\_req\_...” below.

**Produce global rasters of scenario population change, that can be scaled to the GPW.**

1. Calculate change in scenario [pop data in scenarios folder](https://www.dropbox.com/sh/c5hy8el4n4m6ccz/AABoUw6ohq1a-VjwNjQZ5sqNa?dl=0) to get an increase or decrease for each of th~~e~~ scenarios from 2010 to 2050 (2050ssp1,3,5)
   1. use “total” folder (not rural or urban): Spatial\_population\_scenarios\_GeoTIFF\SSP1\_GeoTIFF\total\GeoTIFF
      1. ssp[1\_2050, 3\_2050, 5\_2050] / ssp1\_2010
         1. *~~Output is WORKSPACE/ssp[1,3,5]\_prop\_total.tif~~* ***~~(done)~~***
         2. ***Output is WORKSPACE ssp[1,3,5]\_change\_total (****I can't find a file by this name anywhere. There are files called [ssp[]\_prop\_total](https://www.dropbox.com/sh/kn35gwla3sqkqgs/AAAtqERnwaUoKmVxHmrrfdr5a?dl=0) made 1/26/18 so maybe that's it?****)***
2. Multiply by GPW to get ssp1,3,5 populations
   1. Use gpw-v4-population-count\_2015.tif in [gpw-v4-population-count-2015](https://www.dropbox.com/sh/hgk1hrrx5ghs8hf/AAC5bKCX3UTi9SzUWmQZWQJUa?dl=0) dropbox for water (and CV) *(note this means ssp proportions need to be resized to match GPW rasters)*
      1. ssp[1,3,5]\_gpwpop\_total = ssp[1\_2050, 3\_2050, 5\_2050] / ssp1\_2010 \* gpw-v4-population-count\_2015
         1. *Output is in WORKSPACE/ssp[1,3,5]\_gpwpop\_total.tif* ***(done)***

Use age breakdowns in [gpw-age](https://www.dropbox.com/sh/9ex13bsaa994ukz/AAAaKZv9rUjLvyLfyfciUHOZa?dl=0) dropbox for pollination

* + 1. ssp[ 1| 3 | 5]\_gpwpop\_[014 | 65p][f, | m] = ssp[1\_2050 | 3\_2050 | 5\_2050] / ssp1\_2010 \*gpw\_v4\_e\_[a000\_014ft | a065plusft | a000\_014mt | a065plusmt ]\_2010\_cntm\_30\_sec
    2. ssp[1| 3 | 5]\_gpwpop\_1464[f | m] = ssp[1\_2050, 3\_2050, 5\_2050] / ssp1\_2010 \* (gpw\_v4\_e\_atotpop[f | m]t\_2010\_cntm\_30\_sec  
       - gpw\_v4\_e\_[a000\_014ft | a000\_014mt]\_2010\_cntm\_30\_sec - gpw\_v4\_e\_[a065plusft | a065plusmt ]\_2010\_cntm\_30\_sec)
    3. cur\_gpwpop\_[014 | 65p][f | m] =gpw\_v4\_e\_[a000\_014ft | a065plusft | | a000\_014mt | a065plusmt ]\_2010\_cntm\_30\_sec
    4. cur\_gpwpop\_1564[f | m] = gpw\_v4\_e\_atotpop[f|m]t\_2010\_cntm\_30\_sec  
       - gpw\_v4\_e\_[a000\_014ft | a000\_014mt]\_2010\_cntm\_30\_sec - gpw\_v4\_e\_[a065plusft | a065plusmt ]\_2010\_cntm\_30\_sec

### Dietary requirements

Using sources and assumptions described below, we estimated daily dietary requirements for different demographics for the key nutrients in this analysis, shown below in table 1.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Vitamin A (mcg RE) | folate  (mcg DFE) | Energy  (kcal) |
| 0-14 F | 450 | 250 | 1531 |
| 0 -14 M | 483 | 250 | 1648 |
| 15-64 F | 516 | 408 | 2153 |
| 15-64 M | 600 | 400 | 2675 |
| 65+ F | 500 | 400 | 1876 |
| 65+ M | 600 | 400 | 2318 |
| All population | 533 | 363 | 2173 |

Table 1 - Daily requirement values

The daily requirements values contained were converted to annual requirements per person (conversion factor: 365.25), to match the crop production time step (measured as annual yields). Additionally, energy and vitamin A were converted in kilojoules and International unit, respectively, to match production units (conversion factors: kcal\*4,184 =kJ, and IU=mcg\*2.5; vitamin A conversion factor was estimated as the average of retinol and beta-carotene values, 3.33 and 1.66, respectively).

The table above was binned into age groups to match those in the GPW4 dataset. In order to aggregate finer scale public health data on dietary requirements into these coarser demographics, we made assumptions outlined below in 1.4.3.1-3.

### Micro-nutrients daily dietary requirement values

The **RNI** is the amount of a nutrient that is enough to ensure that the needs of nearly all a group (97.5%) are being met. This metric was used to calculate micronutrient requirements to ensure that it captures the population nutritional needs.

The data was derived from WHO guidelines (Allen 2006)[[7]](#footnote-7), with the following assumptions:

* Averaged values for 2nd trimester pregnant and lactating women
* Averaged requirements for 0-14 age groups using sub-age groups provided by WHO: req0-14y.o = average( reqs1-3y.o ; req4-6y.o ; req19-50y.o)
* Assumed elderly's micronutrients requirements are the same as adults: req64+=req19-50

### Macro-nutrients daily dietary requirement values

The **EAR** is an estimate of the average requirement of energy or a nutrient needed by a group of people: i.e. approximately 50% of people will require less, and 50% will require more. This metric was chosen to calculate macronutrient requirements as it is the common measurement of caloric needs.

The data was derived from British Nutrition Foundation (2016)[[8]](#footnote-8), with the following assumptions:

* Babies: used values for babies fed with *"mixed feeding or unknown feeding"*
* Children: Assuming demographics even for each age group from 0 to 14 y.o
* Adults: Assuming demographics even for each age, averaged over age groups.
* Pregnant women: Using the statement "Energy requirements for pregnant women increase by 0.8 MJ/day or 200 kcal/day, but only in the final three months of pregnancy."
* Elderly*:* Demographics assumption: as many 65-74 as 75+, averaged over these age groups

### Proportion of pregnant women

In addition to the demographics assumptions stated above, for both macro-nutrients and micro-nutrients we used the following method for roughly estimating the proportion of pregnant women in 15-64 female population to be 5.01% using the following reasoning:

ProportionPregnant women in Women15-64 = Fertility\_rate \* t / fertile\_lifetime

where

* ***Fertility\_rate***: number of kids per woman in a lifetime. Fertility\_rate = 2,453 (Data from World Bank 2015[[9]](#footnote-9), accessed online January 2018)
* ***t***: length during which we assume dietary requirements of pregnant/lactating women to be different. We assume t=1 year.
* ***fertile\_lifetime***: 64 – 15 years

This assumes:

* Ignore pregnancy losses and abortions
* t=1 year (including 2nd to 3rd trimesters of pregnancy and a couple months of lactating, which varies a lot – and dietary requirements vary as well from nutrient to nutrient)

### Addendum:

### Aggregation of overall population to calculate potential people fed

As an alternative to local nutritional adequacy, the pollinator-derived production of each nutrient can be converted to the potential number of people whose dietary requirements would be met. For this we suggest using global averages in demographic distributions as a representation of a contribution to the global food system, assuming a 50%/50% gender ratio and the demographics proportions in table 2 from CIA (2010)[[10]](#footnote-10).

|  |  |
| --- | --- |
| Age groups | % Population |
| 0-14 | 26.3 |
| 15-64 | 65.9 |
| 65%+ | 7.8 |

Table 2 - Demographics proportions

### Contribution to local nutritional requirements

Total pollinator-derived micronutrient production is summed to the degree scale, and then divided by total dietary requirements for each nutrient also summed to the degree scale. This then provides a ratio of production to potential local consumption that, while not indicating that the food is in fact consumed locally, does indicate the potential for the production provided by pollination to meet key dietary requirements. This provides a third metric to consider “nature’s contribution to people,” which more explicitly accounts for the actual needs of people. While many scales could be chosen for this aggregation, the original 10 arc seconds resolution was far too fine to be meaningful, and 1 degree was the standard chosen for reporting by IPBES. For each of these contributions, we take the average across all three micronutrients. Because this value of pollination’s contribution to nutritional adequacy will exceed 1 wherever supply exceeds demand, we cap all values at 1 before averaging, since being in surplus on one nutrient does not actually enhance sufficiency on another nutrient.

## Summarizing Results

### Aggregation and Synthesis

All pollinator habitat and production analysis was conducted at the resolution of the GLOBIO land use rasters, 10 arc seconds (~300 m), and final outputs are available at original resolution and also aggregated to the 1 degree resolution (~110 km) for easier visualization of trends at the global scale. For pollinator habitat sufficiency, we report the proportion of 10 arc-second agricultural pixels in a 1 degree cell with sufficient habitat. For micronutrient production we take the sum of the production in each of the 10 arc-second pixels within the 1 degree cell. These production values can be converted to equivalent people whose dietary requirements are met using Tables 1 and 2, but because it is a linear transformation, differences across space or between scenarios will be the same regardless of which metric is used. For all “contributions” (nature’s contribution to pollination and pollination’s contribution to nutrient production and local nutritional adequacy), we aggregate the numerator and denominator to the degree individually first and then divide, rather than averaging across all the 10 second grid cells.

### Outputs

*(10s – globio, 30s – gpw, monfreda 2008 – 5m, ssp – 1/8d)*

At both resolutions:

* **prod\_total\_potential\_en|va|fo\_10s|1d\_cur|ssp1|ssp3|ssp5:** total potential annual production of energy (KJ/yr), vitamin A (IU/yr), and folate (mg/yr) – regardless of whether pollination needs are met
* **prod\_poll\_dep\_potential\_en|va|fo\_10s|1d\_cur|ssp1|ssp3|ssp5**: potential pollination-dependent annual production of energy (KJ/yr), vitamin A (IU/yr), and folate (mg/yr); the amount of all production that is dependent on pollination – regardless of whether those needs are met by surrounding habitat)
* **prod\_poll\_dep\_realized\_en|va|fo\_10s|1d\_cur|ssp1|ssp3|ssp5:** pollination-dependent annual production of energy (KJ/yr), vitamin A (IU/yr), and folate (mg/yr) that can be met by wild pollinators due to the proximity of sufficient habitat.
* **prod\_poll\_dep\_unrealized\_en|va|fo\_10s|1d\_cur|ssp1|ssp3|ssp5:** pollination-dependent annual production of energy (KJ/yr), vitamin A (IU/yr), and folate (mg/yr) that cannot be met by wild pollinators due to a lack of habitat.
* **prod\_poll\_indep\_en|va|fo\_10s|1d\_cur|ssp1|ssp3|ssp5:** pollination-**independent** annual production of energy (KJ/yr), vitamin A (IU/yr), and folate (mg/yr).
* **prod\_total\_realized\_en|va|fo\_10s|1d\_cur|ssp1|ssp3|ssp5:** total realized annual production of energy (KJ/yr), vitamin A (IU/yr), and folate (mg/yr), taking into account pollination needs that have been met by habitat sufficiency
* **nut\_req\_en|va|fo\_30s|1d\_cur|ssp1|ssp3|ssp5**: total annual dietary requirements for energy (KJ/yr), vitamin A (IU/yr), and folate (mg/yr) for the people living on the pixel accounting for age, gender, and population count (finer resolution is at the original gpw resolution of 30s, not globio resolution of 10s).
* **nat\_cont\_poll\_en|va|fo|avg\_10s|1d\_cur|ssp1|ssp3|ssp5**: “nature’s contribution to pollination,” or the realized pollination-dependent production (**prod\_poll\_dep\_realized**) over potential pollination-dependent production (**prod\_poll\_dep\_potential**), for each micronutrient or for the **average (avg)** of all three
* **poll\_cont\_prod\_en|va|fo|avg\_10s|1d\_cur|ssp1|ssp3|ssp5**: “pollination’s contribution to production,” or the realized pollination-dependent production (**prod\_poll\_dep\_realized**) over total realized production (**prod\_total\_realized**), for each micronutrient or for the **average (avg)** of all three

At 10 seconds resolution only:

* **pollhab\_2km\_prop\_on\_ag\_10s\_cur|ssp1|ssp3|ssp5**: proportion of natural habitat within 2km around each pixel of cropland, used to determine habitat sufficiency to receive pollination services

At 1 degree resolution only:

* **poll\_suff\_ag\_coverage\_1d\_cur|ssp1|ssp3|ssp5**: average coverage of agriculture areas that have sufficient natural habitat surrounding it to receive pollination services, assuming a threshold habitat requirement of 30% for full service and full to no service for 30% to 0% coverage.
* **nut\_req\_en|va|fo\_1d\_cur|ssp1|ssp3|ssp5**: total annual dietary requirements for energy (KJ/yr), vitamin A (IU/yr), and folate (mg/yr) for the people living on the pixel accounting for age, gender, and population count.
* **poll\_cont\_nut\_req\_en|va|fo\_1d\_cur|ssp1|ssp3|ssp5**: “nature’s contribution to nutrition,” the contribution of wild pollination to local nutritional adequacy, as a ratio of the realized pollinator-derived production (**prod\_poll\_dep\_realized**) to total dietary requirements (**nut\_req**) for energy, vitamin A, and folate
* **poll\_cont\_nut\_req\_avg\_1d\_cur|ssp1|ssp3|ssp5**: average contribution of wild pollination to local nutritional adequacy, across all three nutrients, with each nutrient capped at 1

In an SQL table, where each row is a 1 degree grid cell:

* grid code (or spatial info for shapefile?)
* country
* subregion ('myregions' in table)
* prod\_poll\_dep\_realized\_en|va|fo\_1d\_cur|ssp1|ssp3|ssp5
* prod\_poll\_dep\_unrealized\_en|va|fo\_1d\_cur|ssp1|ssp3|ssp5
* prod\_total\_realized\_en|va|fo\_1d\_cur|ssp1|ssp3|ssp5
* nut\_req\_en|va|fo\_1d\_cur|ssp1|ssp3|ssp5
* nat\_cont\_poll\_avg\_1d\_cur|ssp1|ssp3|ssp5
* poll\_cont\_prod\_avg\_1d\_cur|ssp1|ssp3|ssp5
* poll\_cont\_nut\_req\_avg\_1d\_cur|ssp1|ssp3|ssp5
* cur|ssp1|ssp3|ssp5gpwpop

(Forget this for now)

* meanPCTu5 (from hunger shapefile)
* meanUW (from hunger shapefile)

1. Kennedy et al. 2013 [↑](#footnote-ref-1)
2. Kremen et al. 2005 [↑](#footnote-ref-2)
3. Chaplin-Kramer et al. 2012 [↑](#footnote-ref-3)
4. Klein et al 2007 [↑](#footnote-ref-4)
5. USDA Nutrient Data Laboratory. 2011 National nutrient database for standard reference. Original table available at: http://ndb.nal.usda.gov. [↑](#footnote-ref-5)
6. Center for International Earth Science Information Network - CIESIN - Columbia University. 2017. Gridded Population of the World, Version 4 (GPWv4): Basic Demographic Characteristics, Revision 10. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). https://doi.org/10.7927/H45H7D7F. [↑](#footnote-ref-6)
7. Allen, L. H., De Benoist, B., Dary, O., Hurrell, R., & World Health Organization, 2006. *Guidelines on food fortification with micronutrients*. [↑](#footnote-ref-7)
8. British Nutrition Foundation, 2016. *Nutrition requirements.* Available online at <https://www.nutrition.org.uk/attachments/article/234/Nutrition%20Requirements_Revised%20Oct%202016.pdf>, accessed January 2018. [↑](#footnote-ref-8)
9. <https://data.worldbank.org/indicator/SP.DYN.TFRT.IN/> [↑](#footnote-ref-9)
10. CIA.gov World FactBook, 2010. *World Statistics* archived February 1, 2010, at WebCite: [https://www.cia.gov/library/publications/the-world-factbook-geos/xx.html](http://www.cia.gov/) [↑](#footnote-ref-10)