# The (non) sense of local food production: Understanding feasibility and environmental impacts of locally sourcing the EAT-Lancet diet.


## Abstract

Both human health and the environment are directly influenced by dietary patterns. The EAT-Lancet commission on Food, Planet, Health has proposed an optimal diet if humanity wants to sustainably feed itself in 2050. Their analysis assumes global trade remains as business as usual. However, locally sourcing food has often been claimed to be less environmentally taxing. This analysis aimed to answer to what extent countries can be self-sufficient in growing the EAT-Lancet diet, and what the impact on land use and reactive nitrogen input to soils would be. Results here show that although a surprisingly large number of countries would be likely to be self-sufficient and some large countries could see environmental benefits, the global reactive nitrogen input and land use would be pushed far outside of planetary boundaries if global food trade were to disappear. This is mainly due to increased livestock consumption and production inefficiencies in Africa and Asia. Ultimately, although the environmental benefits of local production are real in some regions, global trade contributes to an efficient and sustainable global food system.


## Introduction

As the global population increases, so does pressure on the environment through human activities. Not only do the sheer numbers drive up baseline demand for food and shelter, but consumption patterns tend to change to more environmentally taxing forms with increasing per capita affluence (Myers & Kent, 2003). While the UN Human Development Index has increased globally by 21.7% since 1990, with net increases in every country except Syria, the state of the global environment has decreased markedly in this same time span (United Nations Development Programme, 2018). CO2 emissions have risen by 64% since 1990, further driving climate change and ocean acidification (Caldeira & Wickett, 2003; Olivier & Peters, 2018). Over half of all global ice-free land has been directly altered by human activity, driving soil degradation, deforestation, desertification and biodiversity loss (Borrelli et al., 2017; Hooke & Martín-Duque, 2012; Newbold et al., 2015; Smith et al., 2016).

The role of agriculture in these developments cannot be overstated. About 34% of total land is currently used for agriculture, with future increases to be expected (Tilman et al., 2001; WWF, 2016). Besides, as synthetic nitrogen fertilizer from the Haber-Bosch process has enabled feeding the exponential population growth observed over the past century, it has also effectively doubled the release of reactive nitrogen to the environment (Smil, 1999, 2011). This has come with a myriad of issues, such as coastal and freshwater eutrophication, ozone layer depletion, climate change and soil acidification to such an extent that nitrogen application rates have been said to have crossed planetary boundaries (Rockström et al., 2009; Sutton et al., 2011).

However, the gravity of environmental impacts differs significantly between types of food. Where animal products (excluding fish) only make up 17% of consumed calories and 33% of consumed protein, they occupy nearly 80% of agricultural land directly or through feed production (WWF, 2016). Nitrogen use efficiencies also vary between crops and farming techniques, resulting in large differences in uptake and runoff of applied N (van Bueren & Struik, 2017). Dietary patterns thus have major impact on the environment.

Human health is also directly affected by the composition of the diet and by quantity of food intake. Although multiple factors are at play here, dietary changes have contributed to a steady rise of medical conditions such as obesity, diabetes type II and cardiovascular disease. Global obesity rates have nearly tripled since 1975, to a large extent from increases in added sugar to processed food and the affordability of high-calorie processed foods(Drewnowski & Specter, 2004; Malik, Popkin, Bray, Després, & Hu, 2010).

At the same time, around 11% of the world's population remains undernourished, a number that has been steady for some years now after a significant decline. More alarmingly, the number has been rising throughout Africa, and is now at 22.8%. Besides an absolute lack in food quantity, quality is also far from optimal. One in three women globally suffers from anemia through iron deficiency, for example (FAO, IFAD, UNICEF, WFP, & WHO, 2019).

The EAT-Lancet Commission on Food, Planet, Health was established to address the question whether it will be possible to feed global population in 2050 a healthy and sustainable diet. Their analysis has indicated that this would be the case, although it would require significant technological development, a shift in diet and a cutback in food waste and would still be a narrow fit (Willett et al., 2019). Next to this, the analysis assumes a stable worldwide geopolitical situation and free trade.

However, the debate on the benefits and downsides of free trade is not settled. Many have argued that aiming to keep food supply chains local can reduce associated environmental impacts and benefit the local economy, although these claims have been criticized (Edwards-Jones, 2010; Morgan, Marsden, & Murdoch, 2006; Norberg-Hodge, Merrifield, & Gorelick, 2002). Next to this, increases in extreme weather events and general environmental instability decreases reliability of long supply chains, suggesting that countries need to focus on increasing food self-sufficiency to increase their resilience against these developments (Cottrell et al., 2019).

As global free trade not a political given, as seen from the increase in trade wars and calls for protectionism of previous years (Greenaway, Hine, O'Brien, & Thornton, 2016), understanding the potential downsides or benefits of free trade and the resilience (or fragility) of the global food system may serve as a motivator for maintaining good international relations. At the same time, understanding the potential costs or benefits of local food sourcing may aid policy makers in their aim for a sustainable global food system.

In summary, our global food system currently is neither sustainable into the future nor does it lead to optimal nutrition for our global population. Besides that, it is not clear whether global food trade has either a net positive or negative effect on the sustainability of this system. This analysis will investigate to what extent countries could currently self-sustain with a nutritious and sustainable diet as proposed by the EAT-Lancet commission, assuming current production efficiencies, and what the consequences for their land use and soil reactive nitrogen input would be. This would address the question whether the global human population is currently living above the carrying capacity of planet Earth.

# Methodology

In order to calculate the area required for a self-sufficient food system, data on crop yields, livestock yields, food production, population and land use, all for 2016, were taken from FAO. Production was assumed to be ready for consumption, except for oil and sugar crops for which ratios were taken from (INRA, CIRAD, AFZ, & FAO, 2019).

In order to establish an as realistic scenario as possible, consumption of each major source of protein (beef & lamb, pork, poultry, dairy, eggs, fish, nuts, legumes) of each country was assumed to follow the ratios of food supply data of 2013 from FAO. If a group exceeded the upper range for consumption per person per day of the EAT-Lancet guidelines, the excess grams per person per day were evenly distributed over the groups with leftover space.

Average protein content of each protein source group was determined using food supply data from FAO, which reports in both total gram/person/day and g protein/person/day. After this, it was checked whether each country reached the recommended daily protein intake of 0.8 g per kg of bodyweight per day (WHO, FAO, & UNU, 2007). To this end, optimal body weight for adults, assuming a BMI of 20, was calculated per country using average heights obtained from World Population Review (World Population Review, 2019). This was multiplied by 0.8 to obtain total daily protein requirement, and protein from other sources (mainly cereals) was subtracted from this number. If the demand was not reached, all protein source groups with leftover space within the EAT-Lancet ranges were increased evenly until it was. Daily demand per person for each food group was then increased by the percentages from a FAO study on food waste, in order to account for food that is wasted and not consumed (FAO, 2011a).

The total amount of animals required to reach the EAT-Lancet scenario demand was determined by first calculating the total amount of ready-to-cook meat required to reach the demand. As meat production is reported by FAO in dressed carcass weight, dressed carcass demand was determined from ready-to-cook demand using several sources on slaughter yields (Holland, Loveday, & Ferguson, 2019; Oklahoma Department of Agriculture, 2019; Van Leeuwen, 2014). From these numbers, the amount of animals needed for meat, milk and egg production was determined by dividing by FAO livestock yield-per-animal numbers.

Feed demand per animal for different livestock species were adapted from Mottet et al. (2017), who distinguish between regions, species and systems (Grazing, Mixed, Feedlots). The ratios between systems, determined by OECD membership, were directly adapted from this paper. Ratios between crops within a specific feed group (e.g. Oilseed meals) were determined by taking the ratios of business-as-usual (BAU) production numbers. The amount of by-products from food production that can be fed to livestock was determined on a mass basis using numbers from Feedipedia (INRA et al., 2019).

If the amount of by-products produced was insufficient to feed the required livestock, more production of the same type of crop to reach the demand was added. Roughages were excluded as they are implicit in the amount of land used for pasture-raised livestock, which is not included in this analysis. If a country did not initially produce soy or sugar beet/cane, required soy production was added to other oil crop production and sugar beet/cane demand was added to cereal production. Since Mottet et al. (2017) used a dry weight basis, feed demand was converted to wet weight using numbers from Feedipedia (INRA et al., 2019). Ultimately, feed was added to food crop demand.

Nitrogen content of crops was taken from Lassaletta et al. (2014), and numbers on nitrogen use efficiency (NUE) per country and crop were adapted from Zhang et al. (2015). Where NUE numbers were not available, regional averages were used. Regions were based on those used in the IMAGE model (PBL, 2018). Total nitrogen yield per country was then determined by multiplying total crop production by percentage N content of each crop, and then dividing by the NUE.

Land use for food crops was determined per country by dividing total production by yield to obtain total hectare. Land use for stable-reared livestock was estimated using several sources on minimum space recommendations or legal minimum space requirements for animals. A minimum of 45 m2 was assumed for beef cattle based on FAO (2011b). For poultry, 0.3 m2 per animal was assumed based on (FAO, 2019). Pigs were assumed to require at least 10m2 per animal based on research by Wageningen UR Livestock Research (Mul, Vermeij, Hindle, & Spoolder, 2010).

As global data on stocking rates for dairy cows and other pasture-raised animals such as horses seems to be unavailable, the amount of pasture productivity (in kg milk per hectare) required to rear the required animals under the EAT-Lancet scenario was used to estimate feasibility. For this same reason, the amount of required pastureland was not included in the analysis and the amount of roughages required for feeding livestock was excluded as well.

Feasibility of self-sufficiency, defined here as a situation where *production = consumption + waste*, was then estimated for each country by summing the ratio between land required under the EAT-Lancet scenario and total land, and the normalized required milk yields per hectare pasture if pasture were to remain constant. Required milk yields per hectare pasture were normalized with min-max feature scaling to obtain a score between 0 and 1. This score was then divided by 2 and subtracted from 1 to obtain a score between 0 and 1 where 0 is the lowest likelihood and 1 the highest. The self-sufficiency score was thus determined as follows:

$$S_c = 1 - \frac{\frac{Y_c - Y_{max}}{Y_{max} - Y_{min}} + \frac{A_{Lancet,c}}{A_c}}{2}$$

Where $S_c$ is the self-sufficiency score of country c, $Y_c$ is the required milk yields per hectare pasture of country c, $Y_{max}$ and $Y_{min}$ are the maximum and minimum values of required milk yields per hectare pasture worldwide, $A_{Lancet,\,c}$ is the required area under the EAT-Lancet scenario of country c and $A_c$ is the total area of a country.

All calculations were performed in Python 2.7 using the Spyder 3.3.2. GUI.

*Table 1: Summary of methods*

| **Variable** | **Method** | **Source** |
|---|---|---|
| Crop production | Gram of group per day * waste ratio * ratio of crop in crop group production * population * 365 | **Population, ratio:** FAO 2016 |
| Protein source ratios | Adapt Food Supply to EAT-Lancet ratios | **Food Supply:** FAO 2013 |
| Number of animals required | <u>Meat</u>:<br>((Gram per day * waste ratio * population * 365) / ratio of dressed carcass weight to ready to cook meat) / yields<br><u>Milk/eggs:</u><br>((gram per day * waste ratio * population * 365) / yields | **Population**, **yields**: FAO 2016<br><u>Ratios</u>:<br>**Beef**: University of Tennessee<br>**Lamb**: Agriculture and Horticulture Development Board<br>**Pork**: Oklahoma Department of Agriculture |

| | | |
|---|---|---|
| Demand of crop for feed | (Dry mass intake of crop group per animal / dry mass to wet mass ratio of crop) * number of animals required * ratio of crop in total crop group production | **DM intake per animal**: (Mottet et al., 2017)<br>**DM to WM ratio**: Feedipedia<br>**Crop production**: FAO 2016 |
| Required extra crop production if by-products not sufficient | Required amount of by-product – (Crop production * ratio of by-product to product) | **Required amount of by-product**: (Mottet et al., 2017)<br>**Ratio of by-product to product**:<br>Feedipedia |
| Land use | <u>Crops:</u><br>Feed + food crop production / yields<br><u>Stable-reared animals:</u><br>Number of animals * minimum required area | **Yields:** FAO 2016<br>**Minimum required area:**<br>**Beef:** (FAO, 2011b)<br>**Poultry:** (FAO, 2019)<br>**Pork:** (Mul et al., 2010) |
| Nitrogen input | (Crop production * N ratio of crop) / Nitrogen use efficiency of crop | **N ratio of crop:**<br>(Lassaletta et al., 2014)<br>**N use efficiency:**<br>(Zhang et al., 2015) |
| Required milk yields per hectare pasture | Total milk production / total pasture | **Total pasture:** FAO 2016 |
| Likelihood of self sufficiency | $1 - \frac{\frac{\mathrm{Y_c} - \mathrm{Y_{max}}}{\mathrm{Y_{max}} - \mathrm{Y_{min}}} + \frac{\mathrm{A_{Lancet,c}}}{\mathrm{A_c}}}{2}$ | |

# Results

A global overview of the feasibility of self-sufficiency based on land availability under the EAT-Lancet scenario can be seen in Figure 1. Generally, the feasibility of self-sufficiency seems to fairly high, although for countries near the Sahara desert feasibility is noticeably less. Other noticeable countries with a low feasibility of self-sufficiency are Afghanistan, Pakistan and Bangladesh, while neighboring country India seems to be in the area of plausibility. Of developed countries, several countries stand out as being very unlikely to be able to sustain themselves, being South Korea, the United Kingdom and the Netherlands. Besides these three, Japan also has a rather low likelihood to attain self-sufficiency.

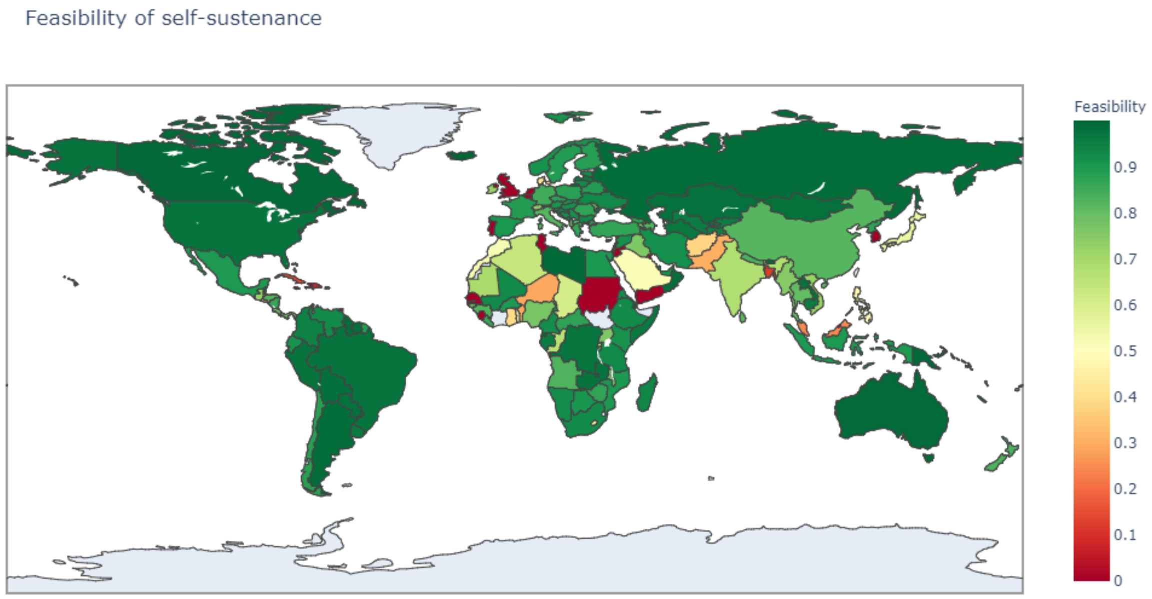


*Figure 1: Feasibility of self-sufficiency under the EAT-Lancet diet*

Global production of each food group under both scenarios can be seen in Figure 2. The proportion of feed is only given for the EAT-Lancet scenario, as Business as Usual also includes feed production determined for export and could thus not be estimated with our method. Most food groups show a decrease under the EAT-Lancet diet scenario, except for fish, unsaturated oils, tree nuts, chicken and other poultry and red and orange vegetables. Almost the entire increase in unsaturated oil crop production can be attributed to increased feed demand. Appendix Section 1 shows regional differences in food group production, with definitions of regions based on the PBL IMAGE 3.0 model given in Appendix Table 1.

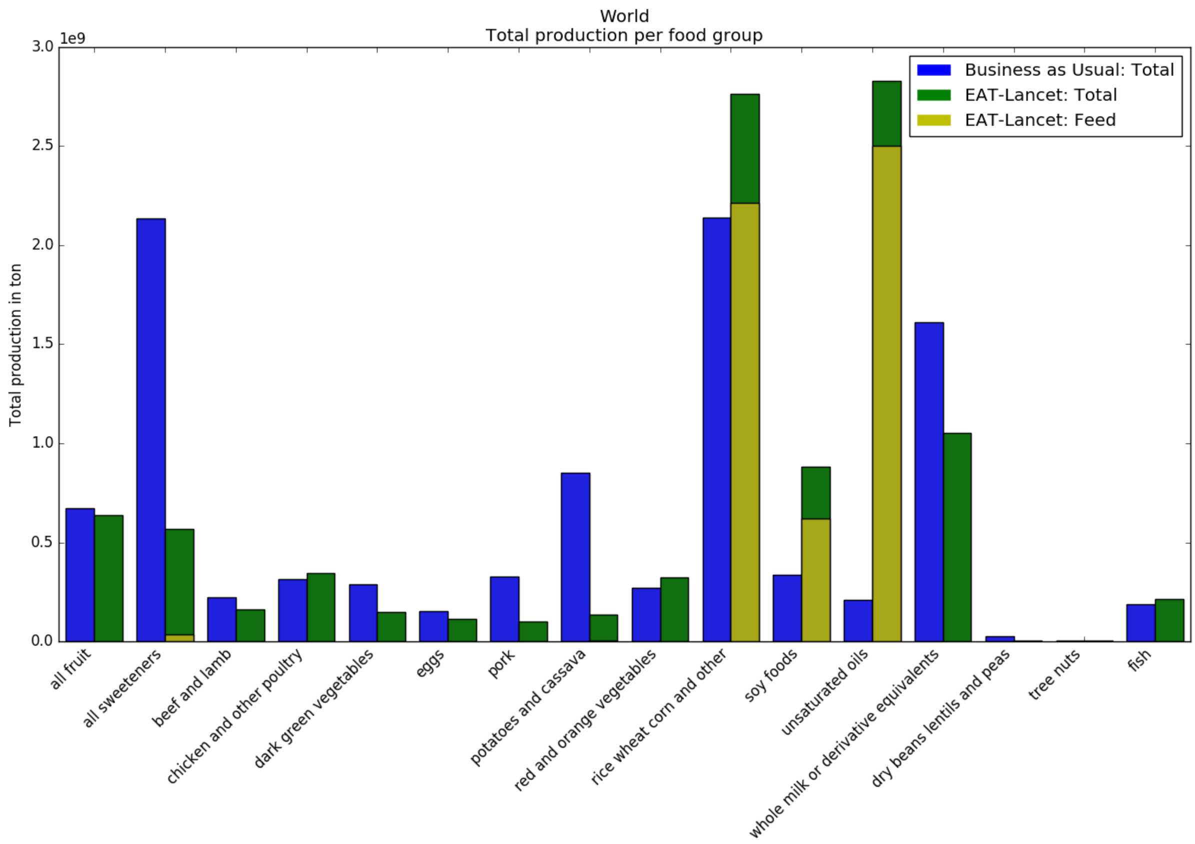


*Figure 2: Yearly global production of food groups in ton*

## North and South America

Between regions, large differences in food group production appeared. Brazil shows a large decrease in sugar crop production, as it is by far the largest producer of sugar cane globally under Business-as-Usual. Soy production also decreases significantly in Brazil under the EAT-Lancet scenario as countries would stop importing feed from this source. Canada shows large decreases in cereal crop and oil crop production, as it would no longer export feed and would produce less livestock products of each category. Central American countries would see a large drop in sugar crop productions under the EAT-Lancet scenario, but a relatively large increase in soy and oil crop production due to minor increases in pork and dairy consumption and local sourcing of feed. In Mexico, a minor increase in poultry and dairy consumption would drive increases in soy and oil crop production.

The United States would significantly decrease its livestock production, with a halving of dairy consumption, a more than twofold reduction in beef and lamb and poultry consumption and a more than 4-fold reduction in pork production. Cereal and soy production in the US would then also fall dramatically by a factor of 12.1 and 4.7 respectively due to decreased demand for feed. Fish consumption, however, would more than double. The same pattern can be observed throughout South America (excluding Brazil), as beef and lamb, dairy, pork and poultry consumption would decrease by a factor of 3.1, 1.3, 1.31 and 1.36 respectively and fish would increase 1.6-fold. This decrease in livestock production and the switch from large exporter to local consumer is also reflected in soy (11-fold decrease) and cereal (5-fold decrease) production.

## Europe and Russia

Similar decreases in livestock consumption can be observed in Europe, with the exception of poultry consumption in Western Europe, which would see a small increase. Pork would see the largest drop in production, with a more than 6 and 4-fold reduction in Western and Eastern Europe respectively, followed by dairy (3.0x and 2.4x decrease) and beef and lamb (2.1 and 1.1x decrease). Fish consumption would increase slightly in Western Europ (1.12x) and somewhat more in Eastern Europe (1.4x). The effects on feed differ markedly between Western and Eastern Europe, as the Eastern European countries that currently do not produce soy would under these assumptions increase their oil crop production. This would be much less the case in Western Europe, which would depend mostly on soy feeds.

Russia would increase its reliance on soy foods as protein sources (2x increase), and decrease all livestock sources except poultry which would stay at the same level (beef/lamb: 1.4x, pork: 2.8x, dairy: 1.5x, eggs: 1.6x). The Ukraine would decrease all its livestock production, implying its current position as a net exporter (beef/lamb: 1.3x, pork: 2.6x, poultry: 1.07x, dairy: 2.3x, eggs: 1.8x). Fish consumption in these regions would increase comparably (1.3x for Russia, 1.27x for the Ukraine).

**Northern Africa and Middle East**

Northern Africa and the Middle East would see a decrease in leguminous protein sources and beef and lamb (8.0x and 1.9x for legumes, and 1.2x and 1.15x for beef and lamb respectively) and an increase in egg (1.5x and 1.35x respectively), fish (1.6x and 1.9x respectively), poultry (1.9x and 1.3x respectively) and dairy consumption (dairy only in North Africa with 1.2x). Pork, while seeing an increase, would remain a negligibly small source of protein, mainly because of Islamic influence in these countries. The effects on feed show similar patterns between the two regions, with large increases in cereals (4.5x and 5x increase respectively), soy (815x and 216x increase respectively) and oil crops (82x and 401x increase respectively) with the latter two showing an especially spectacular increase in production.

**Sub-Saharan Africa**

Most production would consist of feed throughout sub-Saharan Africa, and would shift from roots and tubers to soy and oil crops, and to cereals to a lesser extent. Consumption of livestock products would increase throughout Sub-Saharan African regions (with the exception of beef/lamb and dairy in South Africa), and consumption of legumes would decrease markedly(5.2x in Southern, 7.6x in East, 1.3x in West Africa). West Africa would see a 1.2 increase in beef and lamb production, a 4.3 increase in poultry production, a 2.5x increase in egg production, a 2x increase in pork production and a 1.7x increase in dairy production. East and Southern Africa follow a similar pattern, although beef and lamb production in East Africa would stay at the same level and dairy production would decrease (1.06x) slightly in Southern Africa (East: pork: 2.4x, poultry: 5.9x, dairy: 1.35x, eggs: 3.8x increase. Southern: beef/lamb: 1.6x, pork: 1.9x, poultry: 3x, eggs: 1.6x increase). Fish consumption would increase in East Africa (2.9x), Southern Africa (1.16x), South Africa (1.7x) and West Africa (1.18x).

**Asia**

Regional differences would be large throughout Asia. Central Asia is a large dairy consumer and while showing a 1.6x decrease, dairy would still be the main protein source in the region on a mass basis. Meat consumption would shift from beef and lamb (3.7x decrease) to poultry and pork (4x and 2.1x increase respectively) and local feed production would result in increases in sugar, soy and oil crop production (2.7x, 10.4x and 3.6x respectively). Besides, fish consumption would increase 4.2-fold. This is contrasted by all other Asian regions, which would see increases in beef and lamb production ranging from minor (1.03x in China) to fairly significant (3.4x in India).

China would also see a shift in main protein sources, with a large decrease in pork and (to a lesser extent) egg production (4.9x and 2.1x respectively). This is compensated by increases in poultry (1.9x), dairy (1.6x), fish (1.03x) and possibly soy to some extent, although it is unclear how much soy production under the Business as Usual scenario is allocated to food and feed and thus how large the increase would be under the EAT-Lancet scenario. Most noticeable is the almost absence of non-soy leguminous crop production, as this already is a minor source of food in China under Business as Usual and is thus not represented as much under our EAT-Lancet scenario. Soy crop production, however, would see the largest increase with a factor of 23.2, of which 66% would be used as feed.

India would show increases in all livestock products except dairy, with pork being the largest grower (beef/lamb: 3.4x, poultry: 1.2x, pork: 6.5x, eggs: 1.2x). Fish consumption would also increase by 1.8x. Increases in feed crop production are relative to Business as Usual not large, compared to other countries (3x increase in soy and 1.08x increase in cereals, and a 2x decrease in roots and tubers). The surrounding region of South Asia (excluding India) shows a similar pattern to India as far as livestock products is concerned, with increases in meat (beef/lamb: 1.3x, poultry: 2.3x, pork: 3x) and eggs (2.4x) and a decrease in dairy (1.2x). However, increases in feed crop production would be huge (cereals: 2.5x, soy: 296x, oil crops: 46x) implying a currently large dependency on import.

Beef and lamb, dairy and poultry production would increase in Japan (2.5x, 1.04x, 1.6x respectively), while pork, eggs and fish production would decrease (1.2x, 2x, 1.3x respectively). Japan would also start to rely much more on tree nuts under the EAT-Lancet scenario (68x increase) and local feed production would largely hinder Japan’s chances on self-sufficiency (34x increase in cereals, 78x increase in soy, 1485x increase in oil crops). The Korean peninsula would also show a decrease in pork, eggs and fish, but also dairy (2.3x, 1.4x, 1.3x, 2x respectively) and an increase in beef/lamb and poultry production (2.1x, 1.5x, ), with a very similar effect on feed to Japan (16x increase in cereals, 51x increase in soy, 32x increase in oil crops).

Indonesia would increase production of all livestock products (beef/lamb: 3.3x, poultry: 1.07x, pork: 2.7x, dairy: 1.3x) except eggs (1.2x decrease) and fish (same levels). Soy responds to increased local feed production with a 42x increase, and cereals to a lesser extent with a 1.9x increase. The protein sources of the surrounding countries of South East Asia would remain largely similar, although a shift would occur from pork to beef and lamb (2.6x decrease, 2.04x increase respectively). Dairy production would also increase slightly(1.4x). Increased local feed production would show a very large increase in soy and to a lesser extent oil crops and cereals (112x, 8.3, 5.4x respectively).

**Oceania**

Large decreases in meat consumption would occur in Oceania, especially for beef/lamb and dairy (14x and 6.5x decrease respectively), but also for poultry and pork (1.7x, 1.8x decrease respectively). Fishing would increase a factor of 1.3. Even though meat consumption is decreased by a large factor, locally producing the required feed would still require a 54x increase in soy production and 5.1x increase in oil crop production.

**Nitrogen input and land use**

Global N input under the locally sourced EAT-Lancet scenario would be more than three times higher than the current situation (445 Tg/yr in the EAT-Lancet scenario versus 132 Tg/yr in Business-as-Usual). As can be seen in Figure 3, the differences in total N input would be large and unequally distributed, with the 5 largest nitrogen-consuming countries (Saudi-Arabia, China, Niger, The Netherlands, India) being responsible for 51.1% of total global N input. With the exception of India, these countries also show the largest increase in N input compared to Business as Usual and these 4 together would be responsible for 57% of the total global increase in N input. The Middle East would be responsible for 37.7% of the increase, sub-Saharan Africa for 16%, China for 14.2%. Europe would be responsible for 11.21%, with 11.04% coming from Western Europe. In spite of increasing N input globally total N input would decrease in several large countries, with the largest decreases occurring in the Americas as can be seen in Figure 4. Nevertheless, Mexico and South and Central America would contribute 1.4% and 4.6% to the global increase in N input respectively.

Nitrogen input per hectare (see Figure 5) once again would be unequally distributed with 79.4% of countries having a N input/ha of less than 150kg/ha, but maximum values going up to 601 kg/ha for The Netherlands. The majority (62.3%) of countries would show an increase in N input per hectare, although a significant minority would thus show a decrease.

Global nitrogen input per crop type can be seen in Figure 7Figure 6. Crops for unsaturated oil production contribute the most to the increase in N input under the EAT-Lancet scenario, with more than a 10-fold increase.

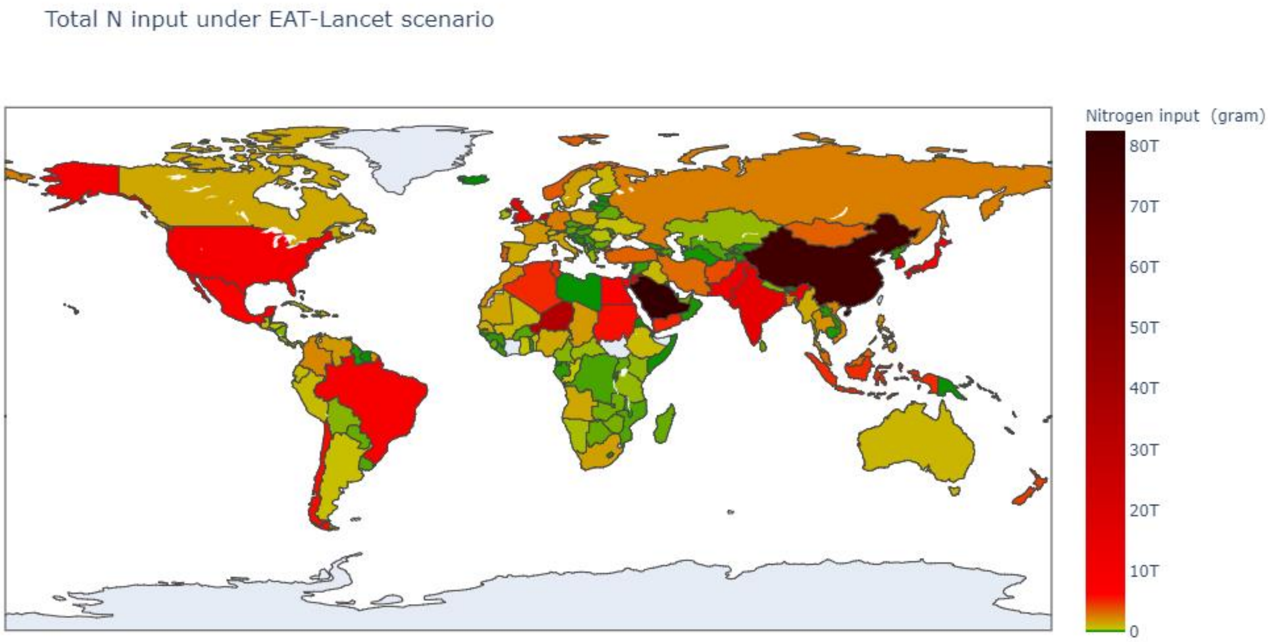


*Figure 3: Total N input in teragram per country per year under EAT-Lancet scenario*

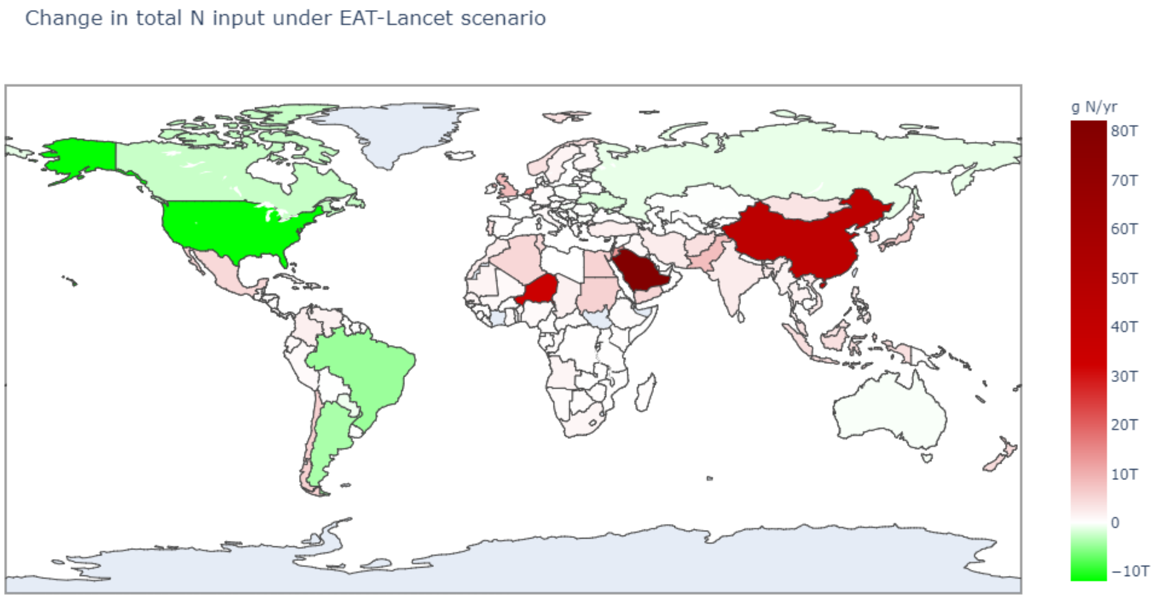


*Figure 4: Change in yearly total N input in teragram per country under EAT-Lancet scenario*

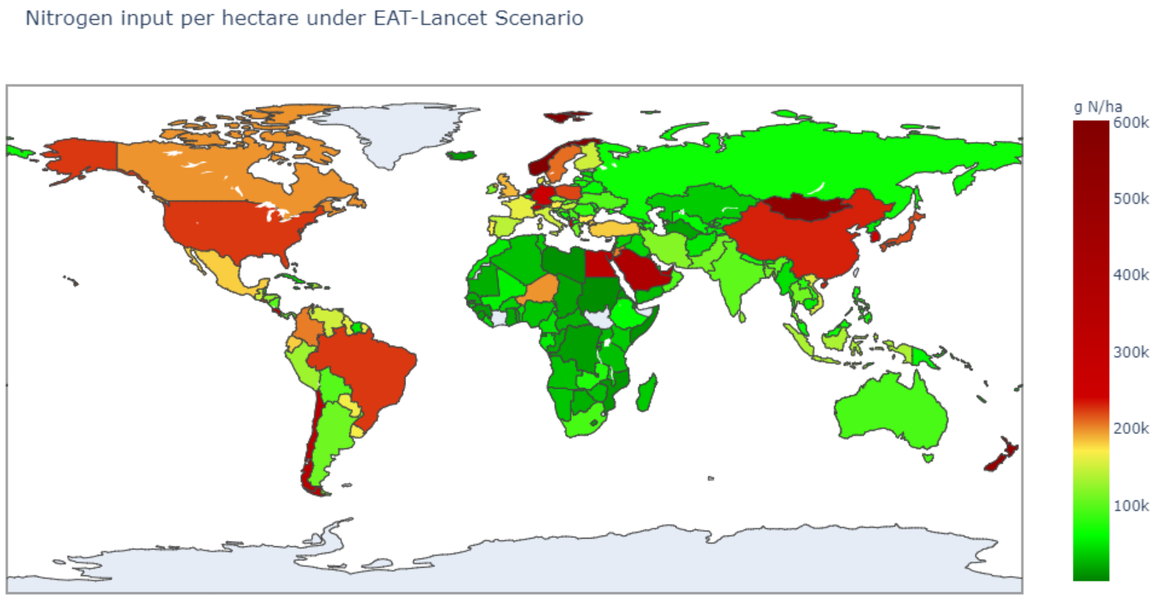


*Figure 5: N input in kg N/ha/year under EAT-Lancet scenario*

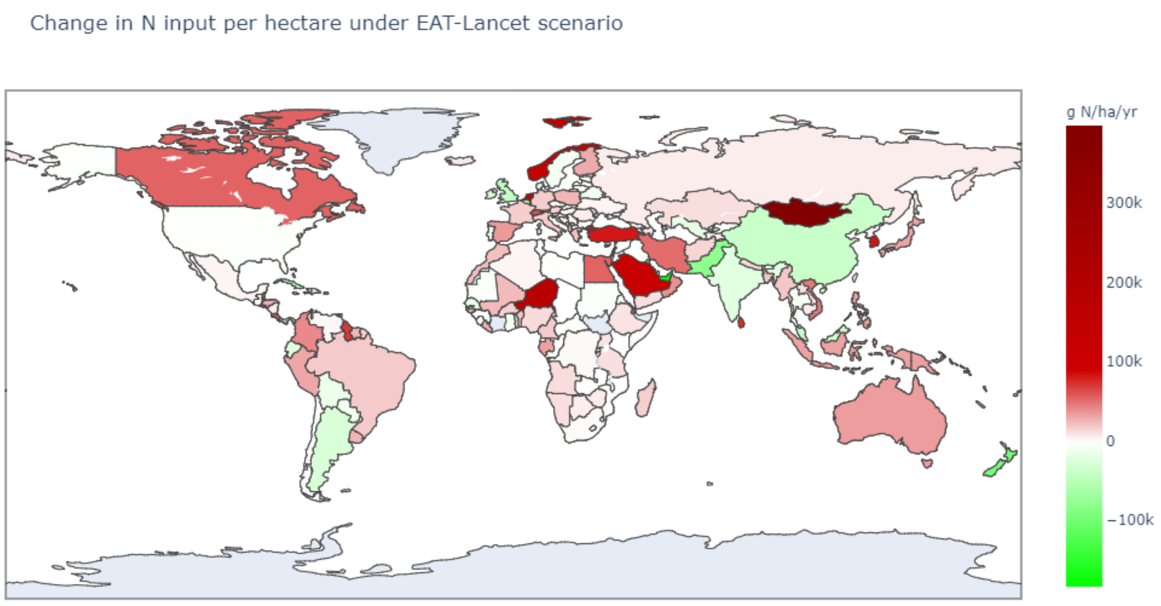


*Figure 6: Change in N input in kg N/ha/year under EAT-Lancet scenario*

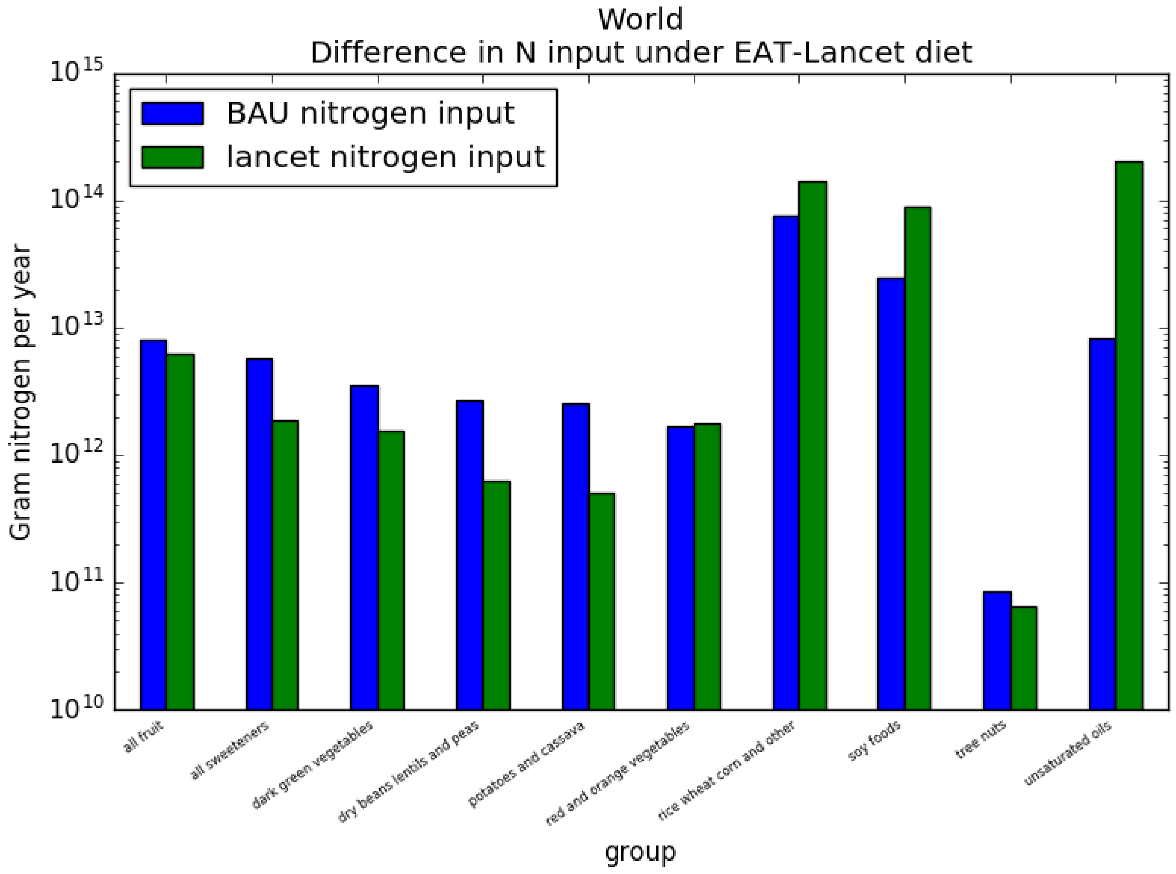


*Figure 7: Yearly total N input in gram per food group under Business as Usual and EAT-Lancet self-sufficient scenarios*

Global land use for agriculture excluding pasture (see Figure 8 & Figure 9) would be more than 4 times higher than Business-as-Usual (4.18e+09 hectare, compared to 9.8e+08 hectare under Business-as-Usual). Of this land use, 84% (3.49e+09 hectare) would be used for growing feed crops under the EAT-Lancet scenario, compared to 65% (6.4e+08 hectare) under Business-as-Usual. Of total global land change, 44.6% could be attributed to increases in Sub-Saharan Africa, 26.3% to increases in North Africa and the Middle East, 6.5% to China and 12.9% to the rest of Asia. Western Europe would contribute 4.1% the increase in land, although Eastern Europe and the Ukraine and Russia would decrease in land used. In the Americas, Canada and the USA would show a decrease in land used, while Mexico would show a 0.8% contribution to the global increase in agricultural land excluding pasture. South and Central America (excluding Brazil, which would show a decrease) would contribute 3.87%.

Global land use for both crops and meat production in stables can be seen in Figure . Once again oil crops stand out with more than a 10 fold increase.

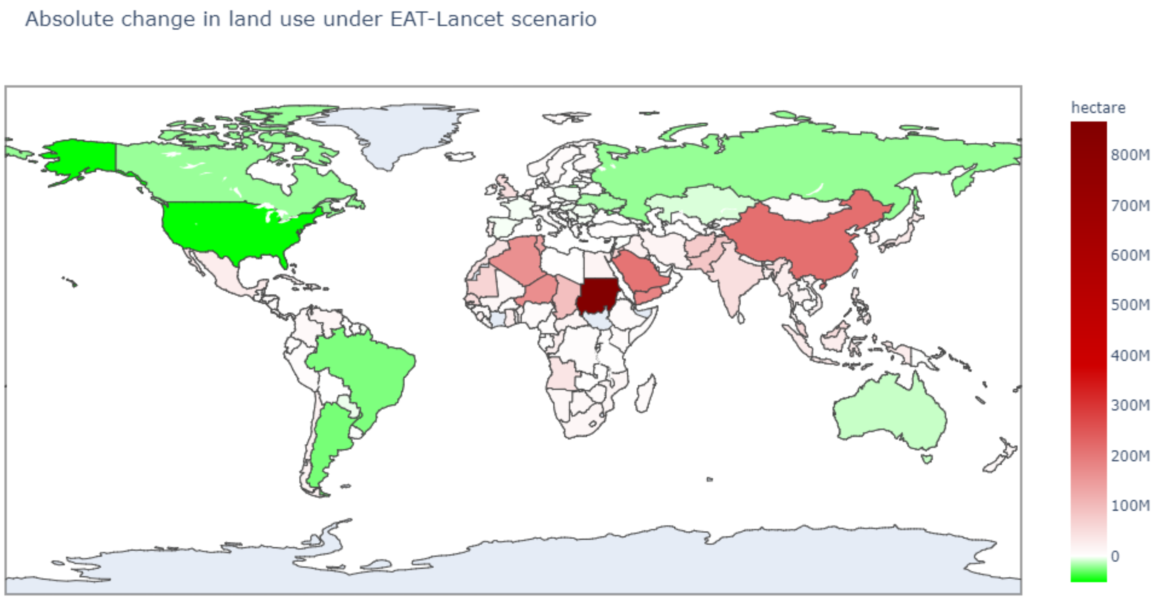


*Figure 8: Absolute changes in total land used for cropland and stable-reared livestock in hectare*

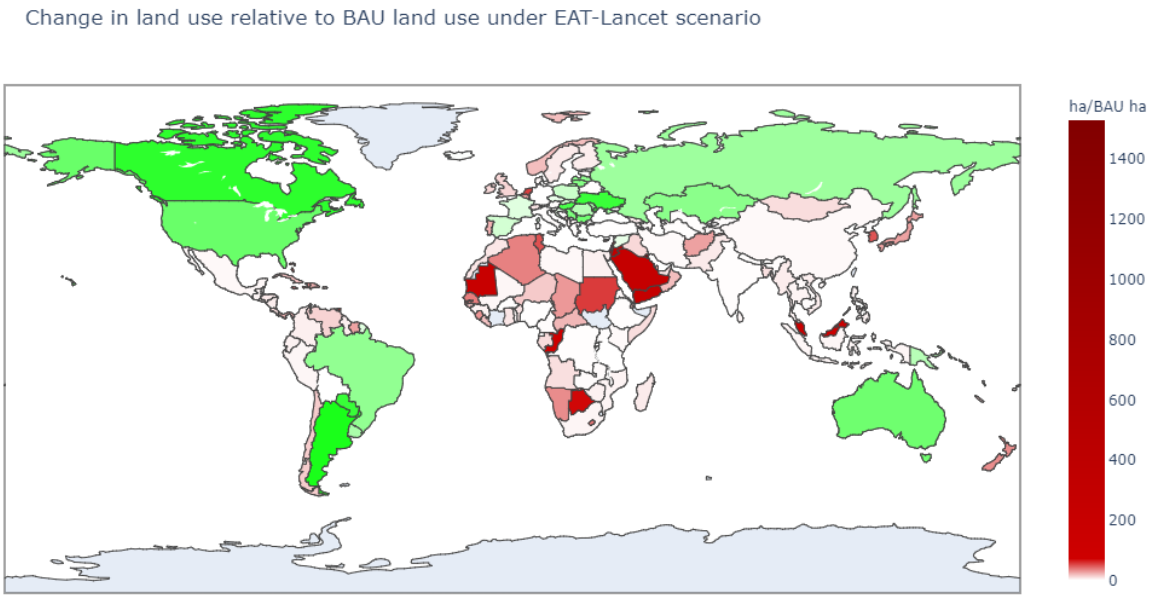


*Figure 9: Change in land use relative to Business as Usual in hectare per hectare*

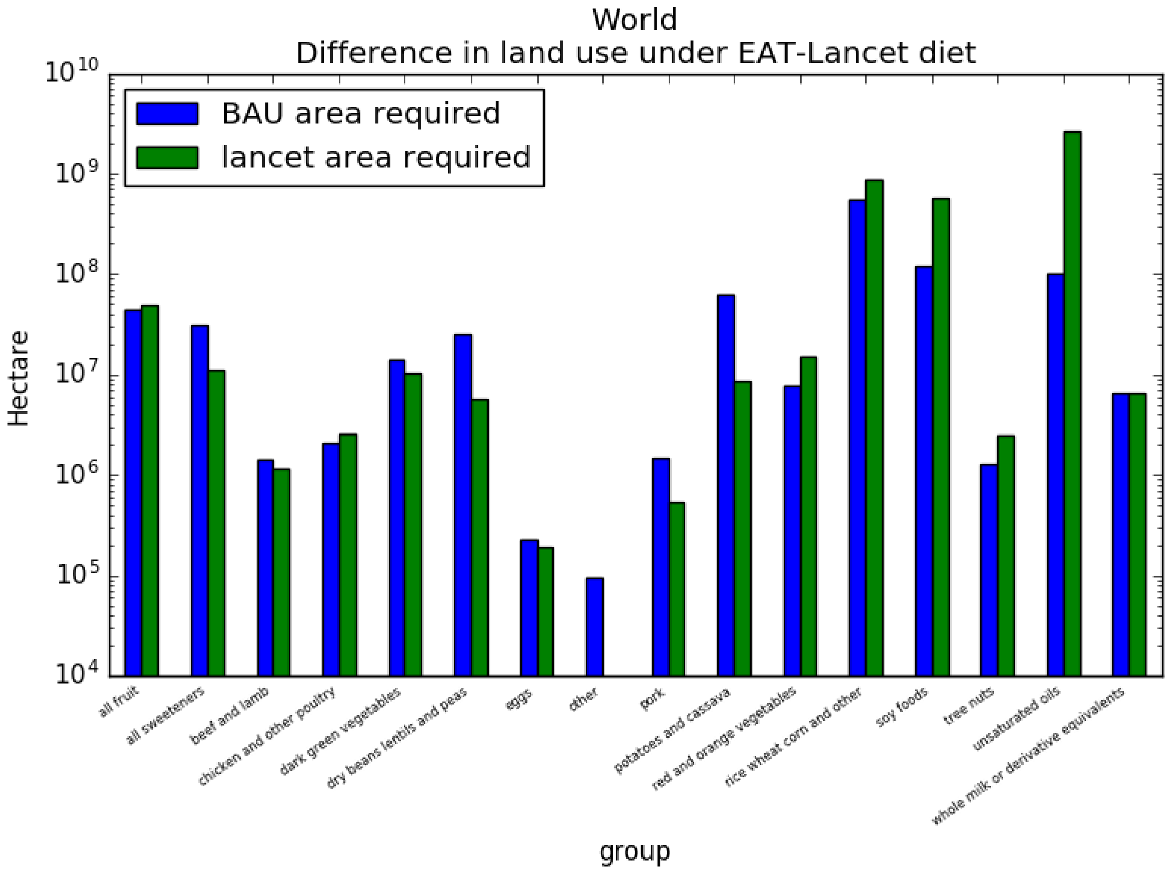


*Figure 10: Global land used for stable-reared livestock and crops under Business as Usual and EAT-Lancet scenarios*

The Spearman rank-order correlation test implied a positive correlation between total land area and likelihood of self-sufficiency ($\rho$ = 0.2939, p-value = 3.193e-05), but not between GDP per capita ($\rho$ = 0.0037, p-value = 0.9593) or population ($\rho$ = -0.0075, p-value = 0.9170) and likelihood of self-sufficiency.

# Discussion

Previous studies assessing national self-sufficiency have mainly done so on a calorie or crop availability basis, and have generally not included livestock production in the analyses (Davis, Gephart, & Gunda, 2016; Porkka, Kummu, Siebert, & Varis, 2013; Simelton, 2011; van Oort et al., 2015). Rutherford (1999) has forecasted the increase in meat and dairy consumption in Asia and the degree of self-sufficiency of each country, but did not include the capacity for domestic feed production. (Gebeltova, 2012; Slaboch & Kotyza, 2016) use a similar methodology of comparing domestic production with domestic demand, but do not include feed production either. To the author's knowledge, this is the first study analyzing the worldwide feasibility of national self-sufficiency with regards to environmental limits for a complete diet that is substantiated to be both healthy and sustainable, including the domestic production of livestock and its required feed.

The value of nitrogen input per year under our self-sufficient EAT-Lancet scenario of 444 Tg/yr would be far outside the limits set in the planetary boundaries framework of 90 Tg/yr, as would the amount of cropland (4.18E+09 hectare under our scenario versus a planetary boundary of 1.10+E09 hectare) (Rockström et al., 2009). This implies that trade is crucial to a sustainable global food system.

Our analysis finds the total amount of land used for croplands and livestock production in stables to be 9.8E+08 hectare under Business as Usual, of which 9.7E+08 (98.8%) is used as cropland and 1.2E+06 (0.2%) for stables. FAO gives the total amount of cropland for 2016 at 1.6+E09 hectare, which is what we find using our methodology if we were to include stimulants and non-food crops. The discrepancy can thus be fully explained this way. Our nitrogen input to croplands under Business as Usual of 132 Tg/yr is similar to the 136 Tg/yr found by (Liu et al., 2010), although the latter value is for the year 2000. Indeed, (Mogollón et al., 2018) find a value of around 170 Tg/yr for 2006. Once again, the exclusion of stimulants and non-food crops could explain a large part of the discrepancy.

(Fader, Gerten, Krause, Lucht, & Cramer, 2013) find fairly different estimations of the likelihood of self-sufficiency. While our analyses both find Northern African and Middle Eastern countries to be least likely to be self-sufficient, they find most of Southern Africa to have too little land whereas we do not find this. Furthermore, contrary to our findings, the large countries Mexico and Mongolia would not be self-sufficient under their assumptions. The presence of the Kalahari desert in Southern Africa, the Gobi desert in Mongolia and the Chihuahuan and Sonoran deserts in northern Mexico could explain these different results, as in the former study a dynamic global vegetation and water balance model for estimating limits to land use/self-sufficiency per country was used. As this model was not available to us, our method was not able to take a countries total land area suited for agriculture into account, and instead had to assume that all countries have equal capacity for expansion relative to their size.

A noticeably large amount of countries would be likely to be able to achieve self-sufficiency under our land use-based criterium, both in developed and developing regions. The absence of a positive correlation between GDP per capita and likelihood of self-sufficiency is surprising given that crop yields in developing countries tend to be much lower. Indeed, (Tittonell & Giller, 2013) identify yields gaps as the main barrier for sustainable intensification in Africa. This hints towards the possibility that most developing countries (especially sub-Saharan Africa, which would require most increases in our scenario) have land area left for agricultural expansion. But while (Headey, 2014) confirms this for sub-Saharan Africa, he also points out that previous estimations of available cropland have been overly optimistic and should also take economic factors into account. Next to this, expansion of agricultural land is inseparably linked with ecological costs, which is supported by (Hosonuma et al., 2012) who identify commercial agriculture as the main driver of deforestation in developing countries.

However, total nitrogen input per hectare of cropland would be very high in a large amount of countries with extremes reaching well over 200kg N/ha/year. In the case of The Netherlands, maintaining ecological quality of freshwater ecosystems has proved to be challenging at nitrogen application limits below 170 kg N/ha/year for most crops, partly because of nitrogen-driven eutrophication of these systems (CBS, PBL, RIVM, & WUR, 2016). It would thus be very unlikely that countries with per hectare application rates above this number would be able to be self-sufficient in a sustainable manner.

Other studies have found highly positive environmental effects of a decrease in animal protein consumption (Haberl et al., 2011; Stehfest et al., 2009). Our analysis finds a net global decrease in consumption of all animal products except poultry and fish (-35.2% compared to the previous value), but suggests that the absence of global trade in food and feed would very likely negate the positive effects on land use and nitrogen input globally speaking. This can be largely explained by both increases in animal product consumption in developing regions, especially sub-Saharan Africa (+44% compared to the previous value), and the accompanying requirement for feed production.

Our methodology for determining feed demand is based on results by (Mottet et al., 2017), which estimates the amount of arable land used for feed production for business as usual at around 40%. Our estimation of cropland used for feed under the EAT-Lancet scenario is 84%. This is high, although current estimates of cropland used for feed vary significantly. Alexander, Brown, Arneth, Finnigan, & Rounsevell (2016) find 57%, while the WWF reports 33% in its 2016 Living Planet Report, based on a report from Metabolic (Gladek et al., 2016; WWF, 2016). This speaks to the large uncertainties in the global livestock system, which varies highly between regions and species as is addressed by (Herrero et al., 2013).

While most increases in land use would occur in sub-Saharan Africa, nitrogen input in this region would still be fairly low. While at first glance this may seem positive, it speaks to the problem addressed by (Tittonell & Giller, 2013) that most African countries under-employ fertilizers and instead rely on nitrogen already present in the soil. This has been a consistent problem throughout sub-Saharan Africa since at least the 1980’s and threatens future soil fertility and food yields (Stoorvogel & Smaling, 1990).

Meanwhile, the top 5 countries contributing most to the global increase in nitrogen input (China, Saudi Arabia, Niger, The Netherlands, Jordan) are fairly evenly distributed geographically speaking, and different explanations can be found for their contributions. While for all countries the increase in N input is driven by extra feed production, only in the case of China the increase in N input can be attributed to a sheer number increase. All other countries in the top 5 would rely heavily on crops with very low nitrogen use efficiencies (NUE). Indeed, while these latter countries would all increase their nitrogen input per hectare cropland, China could decrease its N input per hectare under this scenario.

Even though globally speaking the environmental effects of our scenario would be detrimental, large regions such as the USA, Argentina and Brazil could experience positive environmental effects both on land use and nitrogen input. Since agricultural expansion is generally understood to have been the main driver of deforestation in the Amazon rainforest in Brazil, our analysis suggests that decreasing exports could curb this phenomenon (Nepstad et al., 2009).

Relevant to our scenario of self-sufficiency is the concept of integrated crop-livestock systems. This refers to systems where livestock is reared on crops and roughages produced on location, and is generally claimed to be less environmentally taxing and can increase resilience (Alves, Madari, & Boddey, 2017; Carvalho & Dedieu, 2014). Case studies have shown that this method of farming combined with agroecological principles can decrease environmental impacts and dependency on external inputs while maintaining relevant output and increase resilience towards market turbulence (Bonaudo et al., 2014). For countries that rely mainly on imported feed, our scenario could create the economic conditions that would make this type of agriculture more attractive. This in turn could lead to a reconnection of N and C cycles, as discussed by (Carvalho & Dedieu, 2014), and could to a large extent diminish the environmental issues stemming from global N trade described by (Lassaletta et al., 2014).

Global fish consumption would increase slightly under our scenario. The implications of this would be hard to pinpoint, as they would be highly dependent on what type of fisheries would be used. Marine fish stocks are susceptible to overfishing, and in a world with no food trade preventing a tragedy of the commons might prove difficult (Sumaila, 2017). For landlocked countries, aquaculture and freshwater fish would be the main sources of fish. While these methods might be easier to govern, especially aquaculture usually requires extra feed production and thus more land and nitrogen input (Edwards, 2015).

**Limitations of analysis**

While our scenario assumes upscaling of feed crops in the same ratios as they are currently produced, this does not include any economic effects such as price elasticities or economies of scale. It is not unreasonable to assume that countries would switch to higher yielding, cheaper feed crops such as soy and maize instead of scaling up more expensive, lower yielding oil crops such as olives.

These points gives reason to assume an overestimation of global feed demand and its environmental impacts in our analysis, but there are several reasons for assuming the opposite. The global demand for feed is likely to be higher in reality, as our analysis does not include feed that is wasted. Global feed demand is further expected to be underestimated in our analysis as feed demand for aquaculture is not included. Our analysis could also be improved by including herd dynamics, as the required herd sizes and fecundity rates to sustain livestock populations are currently not taken into account. This means that it is likely that our analysis underestimates the amount of animals and thus the amount of feed required under the EAT-Lancet scenario.

Required increases in pasture are not included in this analysis as pasture productivity varies highly between regions and global data on this is not available. Even though the amount of pasture globally seems to be on the decline while global meat and dairy consumption has risen this effect would very likely disappear under our scenario due to increase livestock production in developing countries, which are expected to have lower yield numbers (Alexandratos & Bruinsma, 2012; Poore, 2016).

Our analysis does not distinguish between forms of N input, although the environmental effects may vary significantly due to variance in uptake efficiency of crops between these sources (McNeill & Unkovich, 2007). Globally speaking, it could be the case that N input would start to depend more on synthetic fertilizers and fixation and less on animal manure as livestock numbers decline and soy production increases. On the other hand animal manure could become a more prominent source of N as integrated crop-livestock systems become more economically attractive due to land limitations.

Lastly, there are uncertainties intrinsic to the sources used. The conversion factors of dressed carcass weight to ready-to-cook meat came from a variety of grey literature sources and may vary between countries, as may the amount of by-products produced that are used for animal feed.

# Conclusion

Although some countries would be likely to be able to sustain themselves under the EAT-Lancet diet scenario, most countries would not be able to reach self-sufficiency without suffering mayor environmental damage from either land use increase or increased nitrogen input per hectare. This suggests that even though the EAT-Lancet diet is intended to keep us within planetary boundaries, lack of specialization in feed production, increases in livestock product consumption in developing countries and low nitrogen use efficiencies would push land use and nitrogen input far outside of planetary boundaries if every country were to become self-sufficient. Thus, while some countries could see environmental benefits of local production, trade appears to be a key element of reaching the goals of the EAT-Lancet Commission. However, there is much room for improving production practices in developing countries. Therefore, more research is needed in order to predict increases in production efficiency with economic development in developing countries, and reevaluate the results found in this study based on predictions towards the future.

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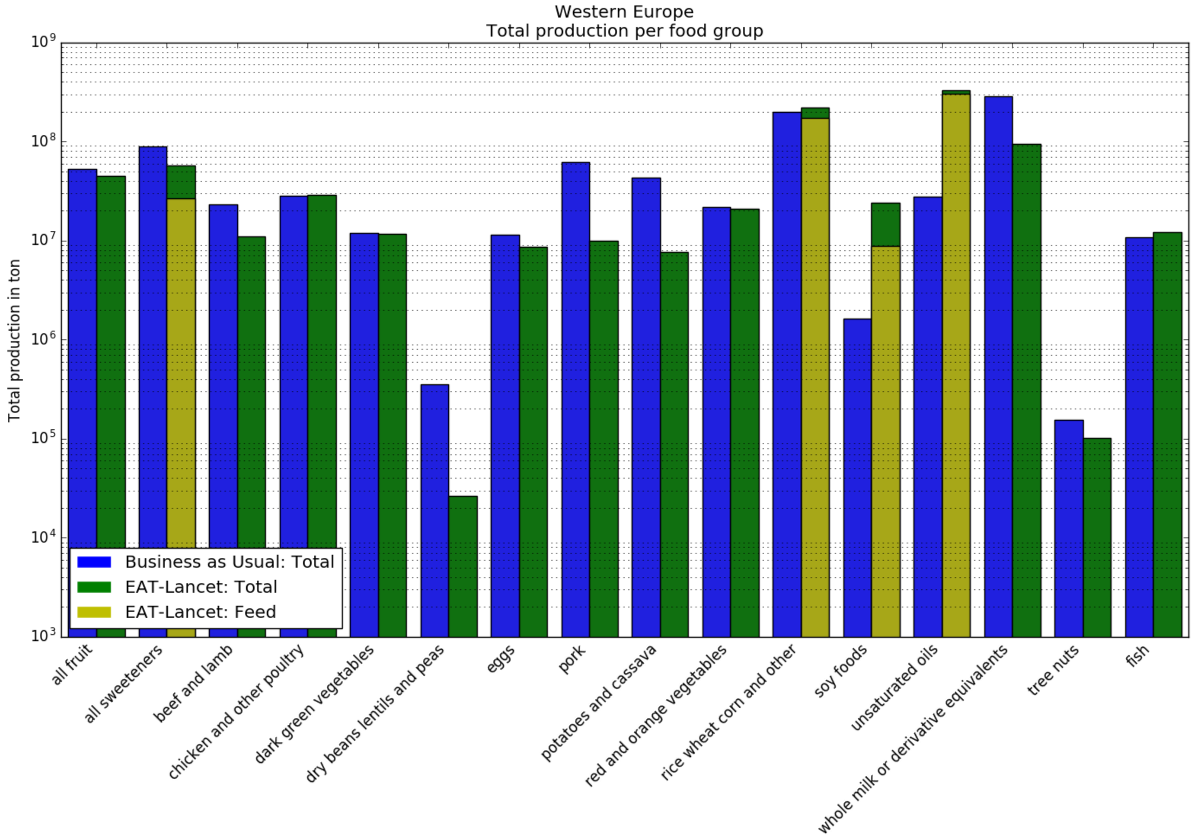
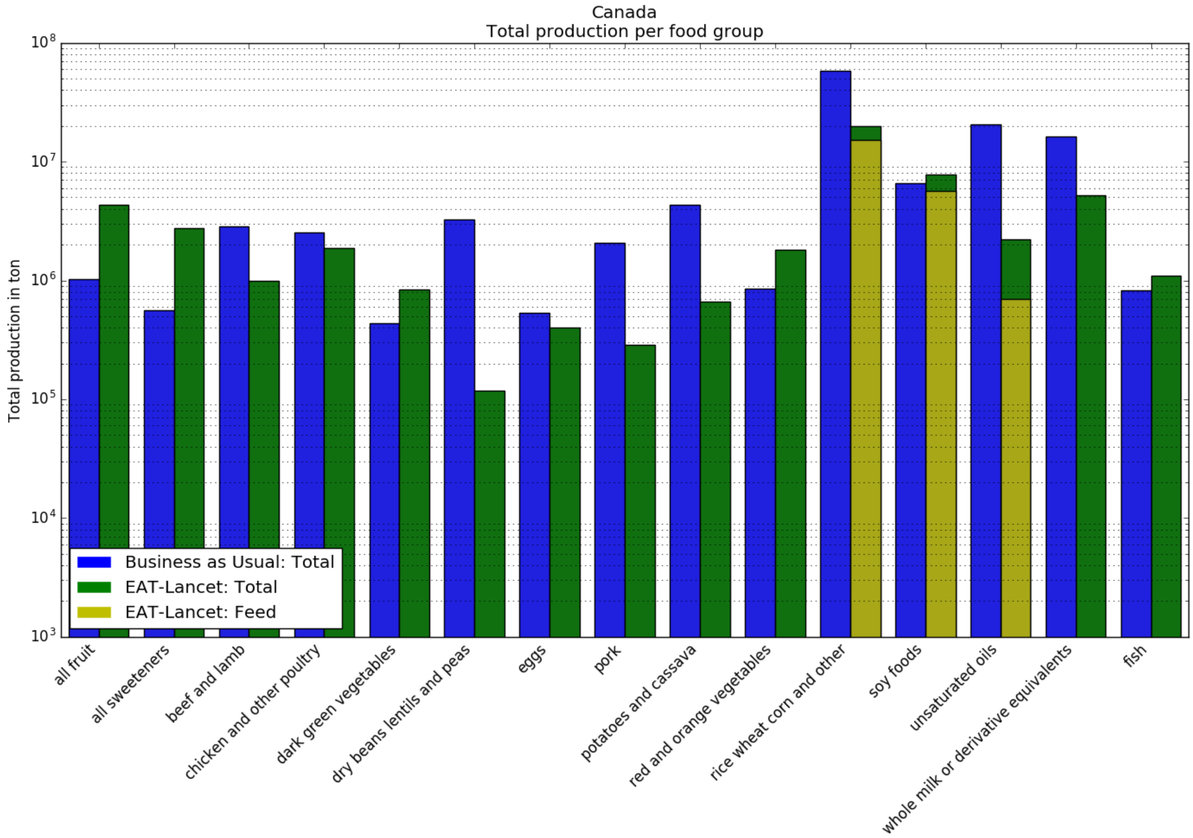
# Appendix

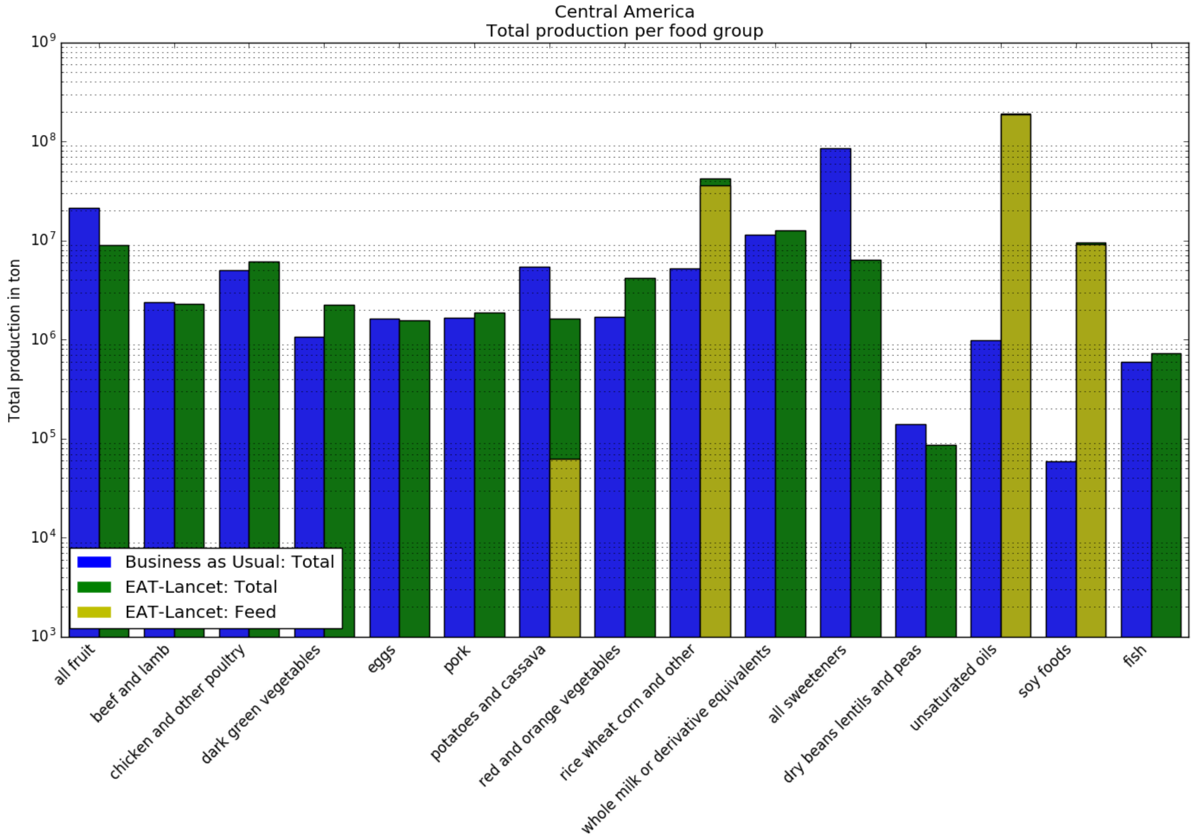
| Region | Countries |
|---|---|
| Canada | Canada |
| USA | St. Pierre and Miquelon , United States |
| Mexico | Mexico |
| Central America | Bahamas, The , Barbados , Bermuda , Belize , Virgin Isl. (Br.) , Cayman Islands , Costa Rica , Dominica , Dominican Republic , El Salvador , Grenada , Guadeloupe , Guatemala , Haiti , Honduras , Jamaica , Martinique , Montserrat , Aruba , Netherlands Antilles , Nicaragua , Panama , Puerto Rico , St. Kitts and Nevis , Anguilla , St. Lucia , St. Vincent and the Grenadines , Trinidad and Tobago , Turks and Caicos Isl. , Virgin Islands (U.S.) |
| Brazil | Brazil |
| Rest of South America | Argentina , Bolivia , Chile , Colombia , Ecuador , Falklands Isl. , French Guyana , Guyana , Paraguay , Peru , Suriname , Uruguay , Venezuela, RB |
| Northern Africa | Algeria , Libya , Morocco , Western Sahara , Tunisia , Egypt, Arab Rep. |
| Western Africa | Cameroon , Cape Verde , Central African Republic , Chad , Congo, Rep. , Congo, Dem. Rep. , Benin , Equatorial Guinea , Gabon , Gambia, The , Ghana , Guinea , Cote d'Ivoire , Liberia , Mali , Mauritania , Niger , Nigeria , Guinea-Bissau , St. Helena , Sao Tome and Principe , Senegal , Sierra Leone , Togo , Burkina Faso |
| Eastern Africa | Burundi , Comoros , Ethiopia , Eritrea , Djibouti , Kenya , Madagascar , Mauritius , Reunion , Rwanda , Seychelles , Somalia , Sudan , Uganda |
| South Africa | South Africa |
| Western Europe | Andorra , Austria , Belgium , Denmark , Faeroe Islands , Finland , France , Germany , Gibraltar , Greece , Vatican City State , Iceland , Ireland , Italy , Liechtenstein , Luxembourg , Monaco , Netherlands , Norway , Portugal , San Marino , Spain , Sweden , Switzerland , United Kingdom , Malta |
| Central Europe | Albania , Bosnia and Herzegovina , Bulgaria , Croatia , Cyprus , Czech Republic , Estonia , Hungary , Latvia , Lithuania , Macedonia, FYR , Poland , Romania , Serbia and Montenegro , Slovak Republic , Slovenia |
| Turkey | Turkey |
| Ukraine | Belarus , Moldova , Ukraine |
| Central Asia | Kazakhstan , Kyrgyz Republic , Tajikistan , Turkmenistan , Uzbekistan |
| Russia | Azerbaijan , Armenia , Georgia , Russian Federation |
| Middle East | Bahrain , Iran, Islamic Rep. , Iraq , Israel , Jordan , Kuwait , Lebanon , Oman , Qatar , Saudi Arabia , Syrian Arab Republic , United Arab Emirates , Yemen, Rep. |
| India | India |
| Korea region | Korea, Dem. Rep. , Korea, Rep. |
| China region | China , Taiwan , Hong Kong, China , Macao, China , Mongolia |
| Southeastern Asia | Brunei , Myanmar , Cambodia , Lao PDR , Malaysia , Philippines , Singapore , Vietnam , Thailand |
| Indonesia | Indonesia , Papua New Guinea , East Timor |
| Japan | Japan |
| Oceania | American Samoa , Australia , Solomon Islands , Cook Isl. , Fiji , French Polynesia , Kiribati , Nauru , New Caledonia , Vanuatu , New Zealand , Niue , Northern Mariana Islands , Micronesia, Fed. Sts. , Marshall Islands , Palau , Pitcairn , Tokelau , Tonga , Tuvalu , Wallis ans Futuna Island , Samoa |
| Rest of South Asia | Afghanistan , Bangladesh , Bhutan , Maldives , Nepal , Pakistan , Sri Lanka |
| Rest of Southern Africa | Angola , Botswana , Lesotho , Malawi , Mozambique , Namibia , Zimbabwe , Swaziland , Tanzania , Zambia |

*Appendix Table 1: Countries contained in regions*

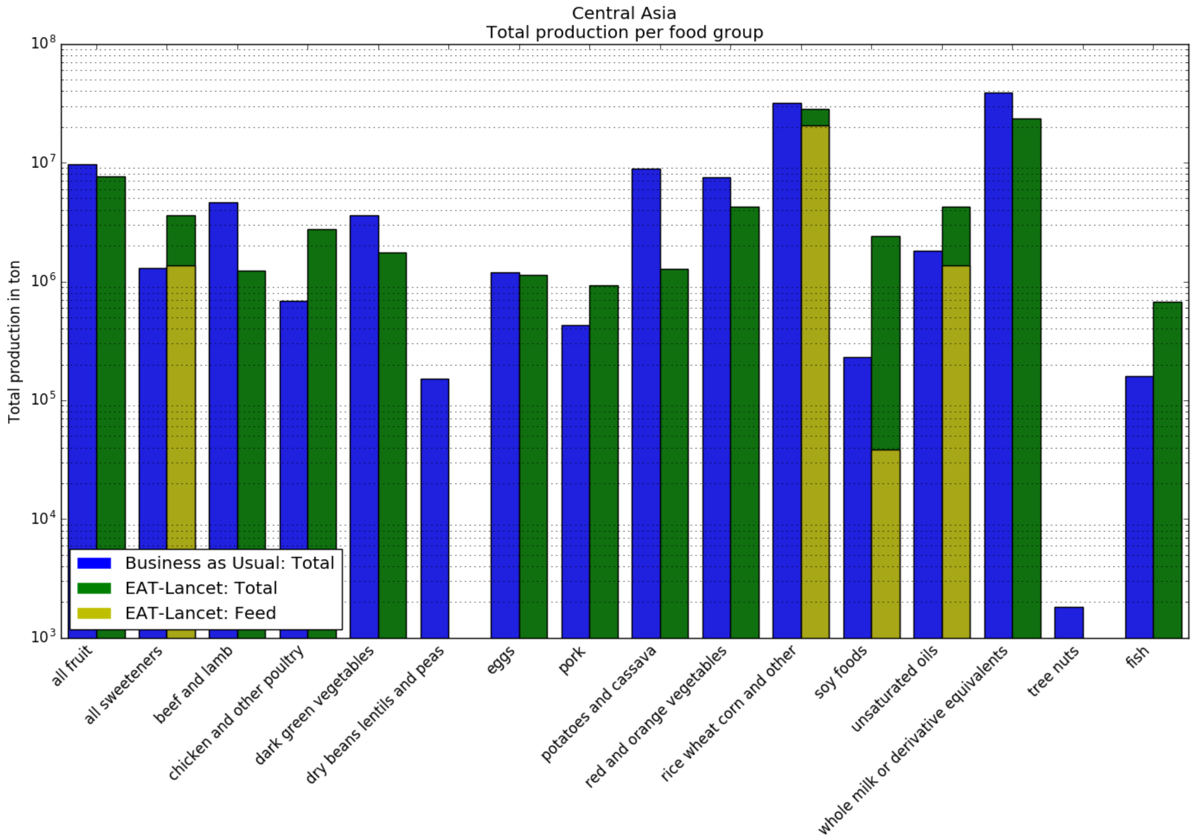
## Section 1: Food group production per region


Western Europe
Total production per food group
Total production in ton
$10^3$
$10^4$
$10^5$
$10^6$
$10^7$
$10^8$
$10^9$
Business as Usual: Total
EAT-Lancet: Total
EAT-Lancet: Feed
all fruit
all sweeteners
beef and lamb
chicken and other poultry
dark green vegetables
dry beans lentils and peas
eggs
pork
potatoes and cassava
red and orange vegetables
rice wheat corn and other
soy foods
unsaturated oils
whole milk or derivative equivalents
tree nuts
fish

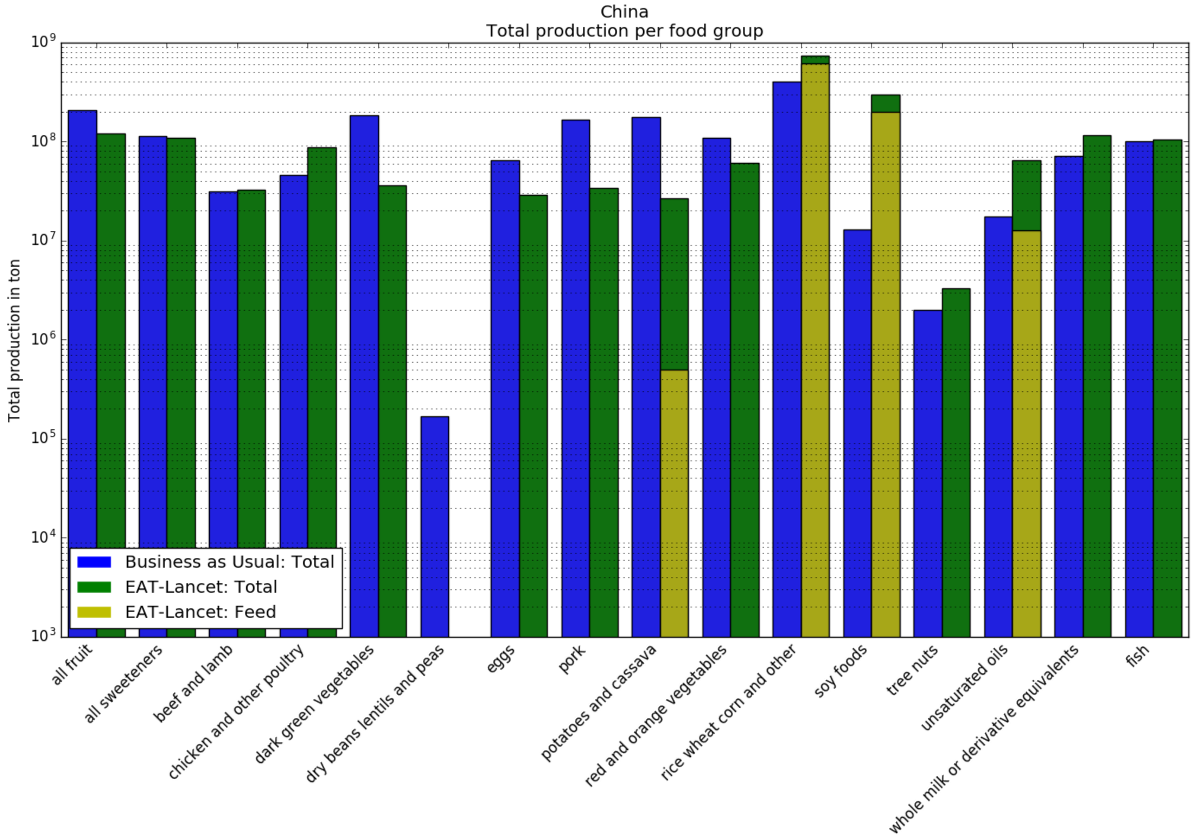

Canada
Total production per food group
Total production in ton
$10^3$
$10^4$
$10^5$
$10^6$
$10^7$
$10^8$
Business as Usual: Total
EAT-Lancet: Total
EAT-Lancet: Feed
all fruit
all sweeteners
beef and lamb
chicken and other poultry
dark green vegetables
dry beans lentils and peas
eggs
pork
potatoes and cassava
red and orange vegetables
rice wheat corn and other
soy foods
unsaturated oils
whole milk or derivative equivalents
fish

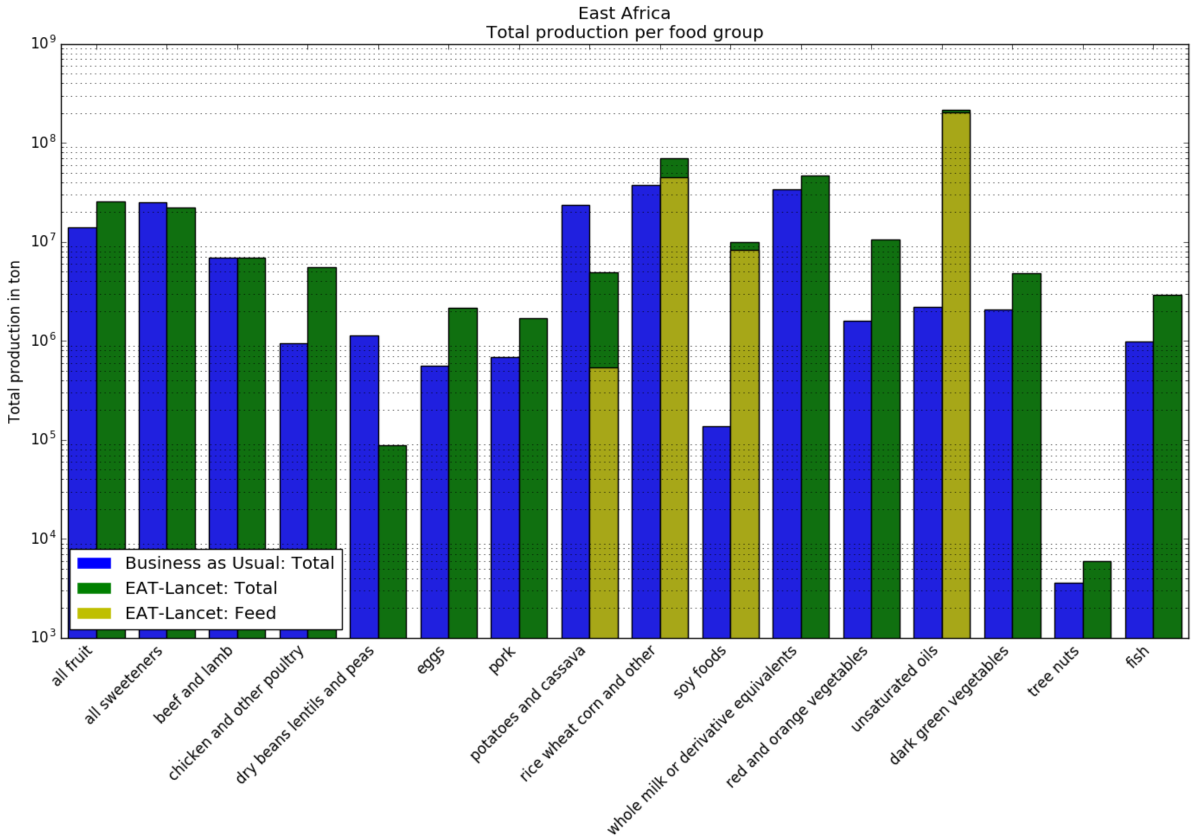


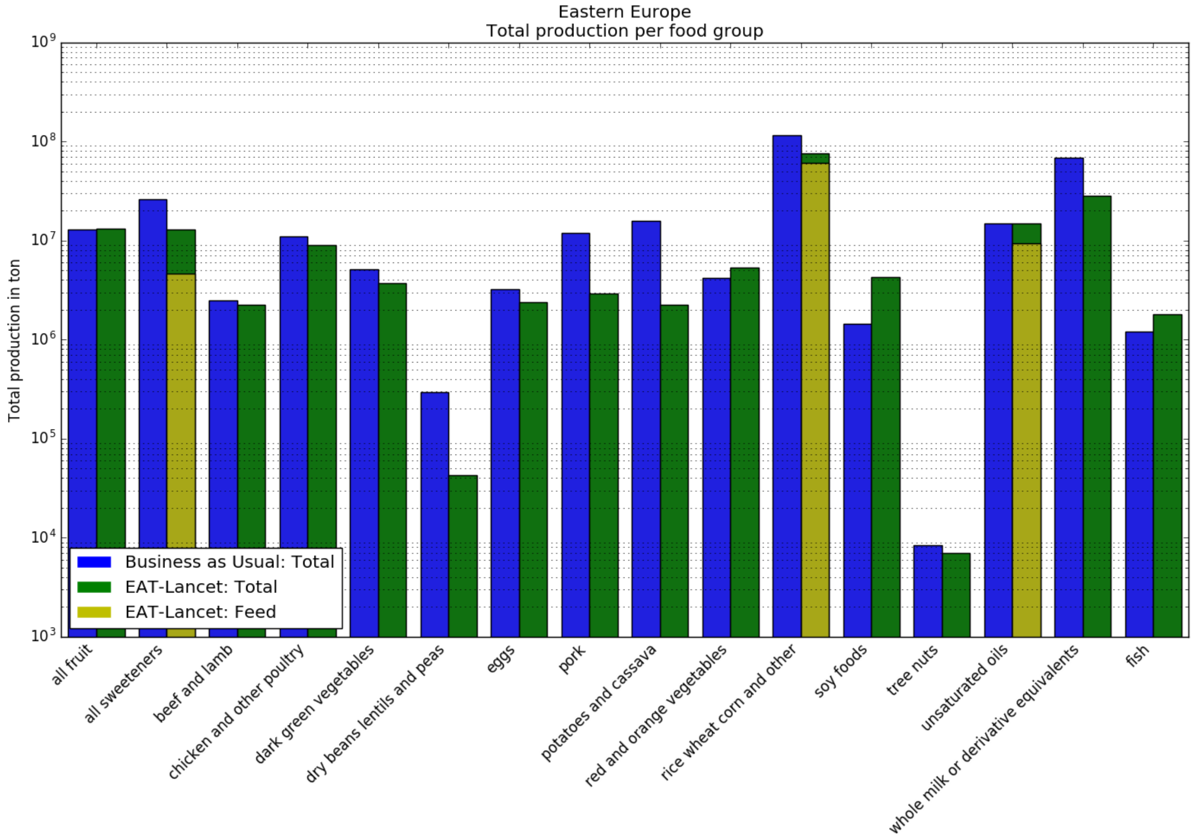
Central America
Total production per food group
Total production in ton
Business as Usual: Total
EAT-Lancet: Total
EAT-Lancet: Feed
all fruit
beef and lamb
chicken and other poultry
dark green vegetables
eggs
pork
potatoes and cassava
red and orange vegetables
rice wheat corn and other
whole milk or derivative equivalents
all sweeteners
dry beans lentils and peas
unsaturated oils
soy foods
fish

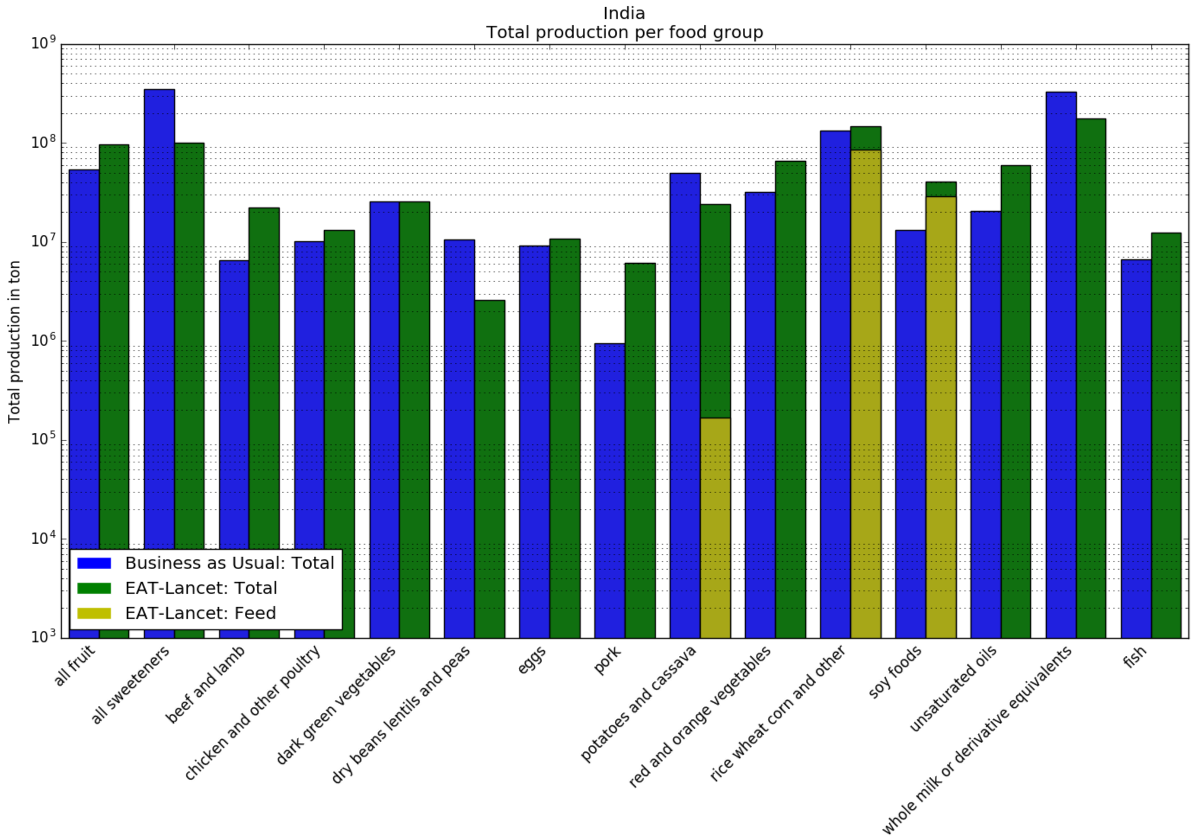



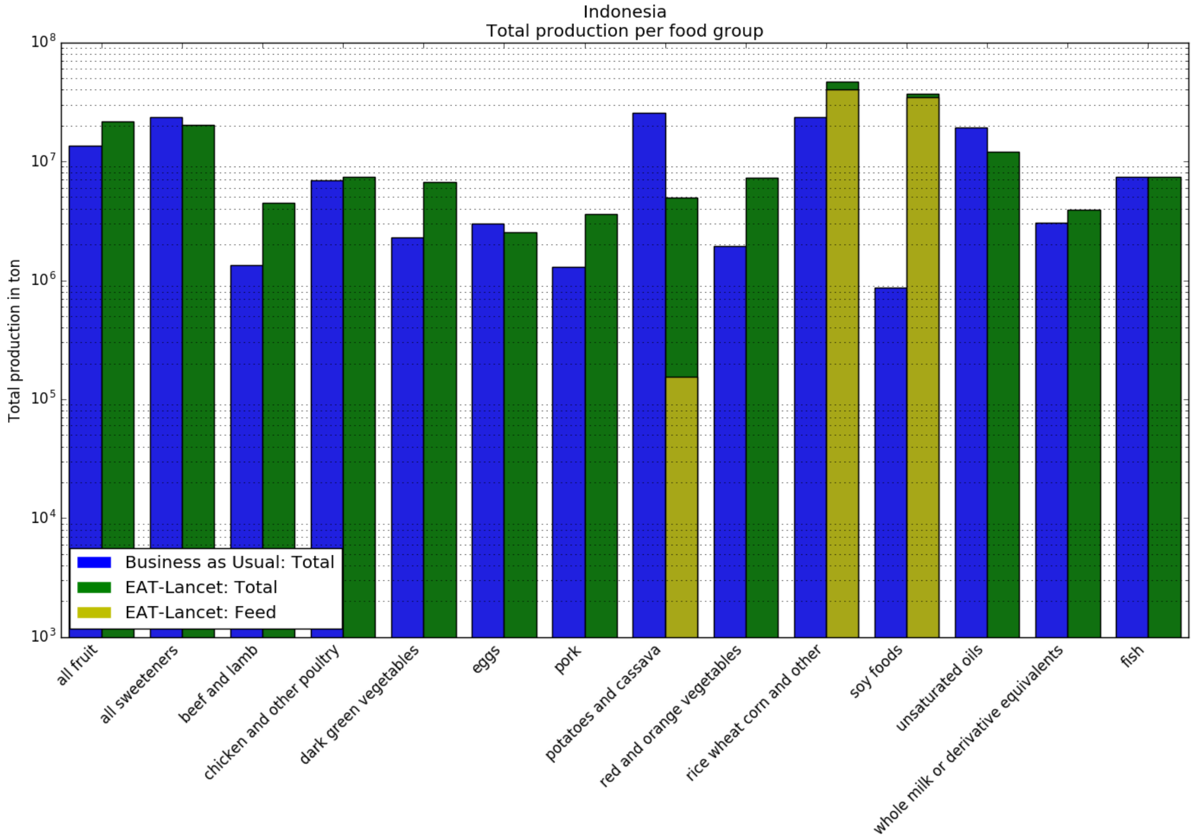
Central Asia
Total production per food group
Total production in ton
Business as Usual: Total
EAT-Lancet: Total
EAT-Lancet: Feed
all fruit
all sweeteners
beef and lamb
chicken and other poultry
dark green vegetables
dry beans lentils and peas
eggs
pork
potatoes and cassava
red and orange vegetables
rice wheat corn and other
soy foods
unsaturated oils
whole milk or derivative equivalents
tree nuts
fish

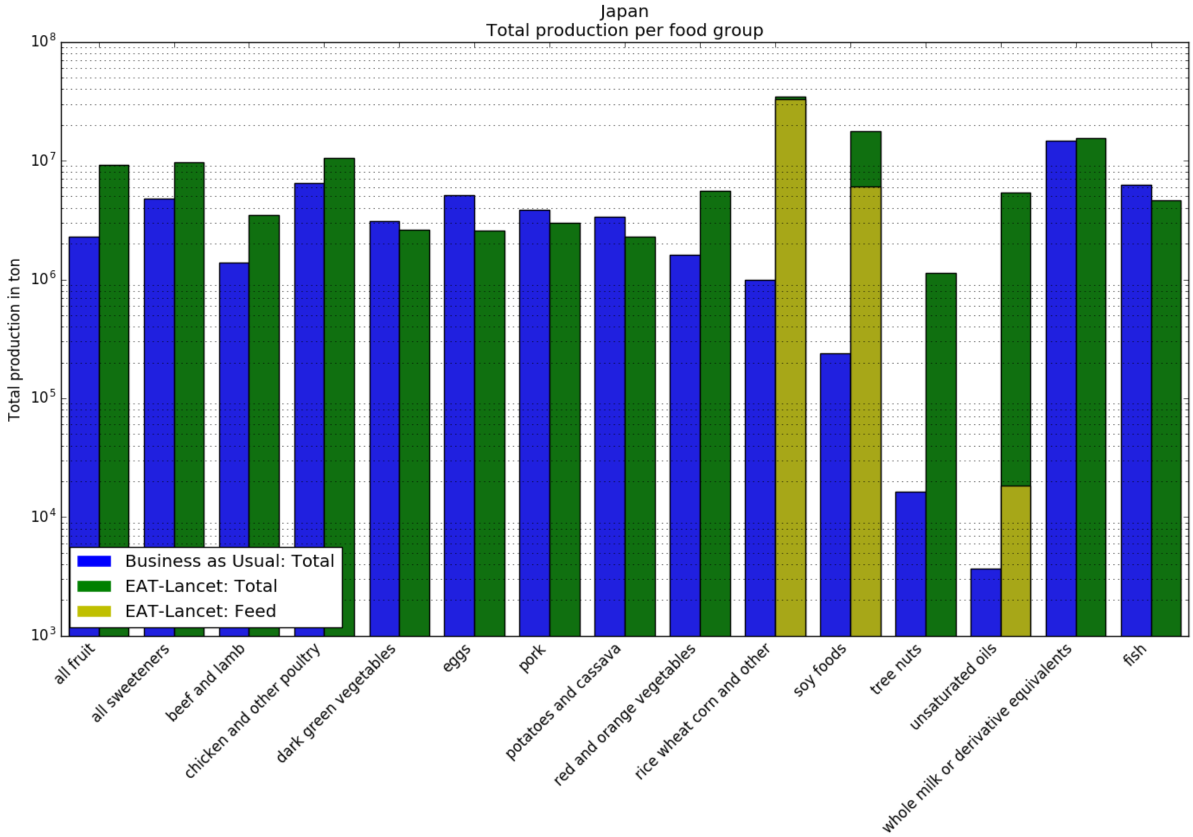

China
Total production per food group
Total production in ton
$10^3$
$10^4$
$10^5$
$10^6$
$10^7$
$10^8$
$10^9$
Business as Usual: Total
EAT-Lancet: Total
EAT-Lancet: Feed
all fruit
all sweeteners
beef and lamb
chicken and other poultry
dark green vegetables
dry beans lentils and peas
eggs
pork
potatoes and cassava
red and orange vegetables
rice wheat corn and other
soy foods
tree nuts
unsaturated oils
whole milk or derivative equivalents
fish

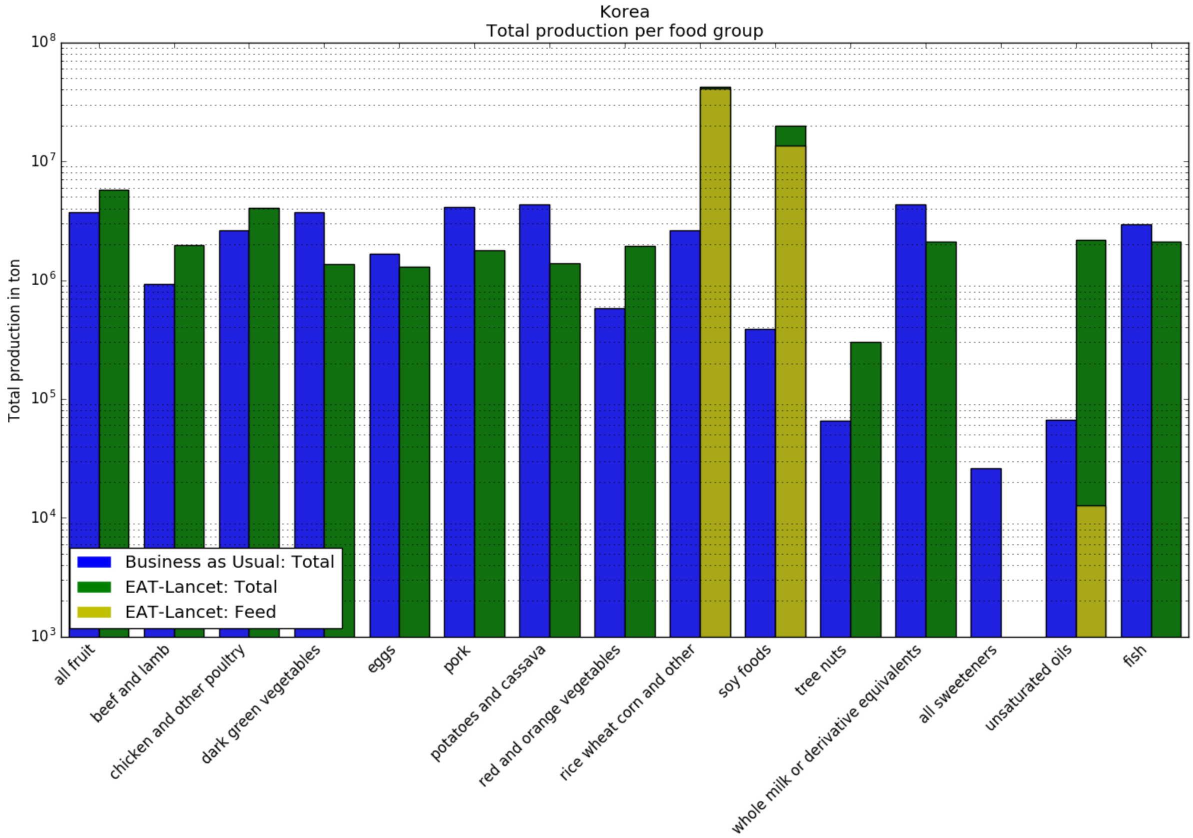

East Africa
Total production per food group
Total production in ton
$10^3$
$10^4$
$10^5$
$10^6$
$10^7$
$10^8$
$10^9$
Business as Usual: Total
EAT-Lancet: Total
EAT-Lancet: Feed
all fruit
all sweeteners
beef and lamb
chicken and other poultry
dry beans lentils and peas
eggs
pork
potatoes and cassava
rice wheat corn and other
soy foods
whole milk or derivative equivalents
red and orange vegetables
unsaturated oils
dark green vegetables
tree nuts
fish

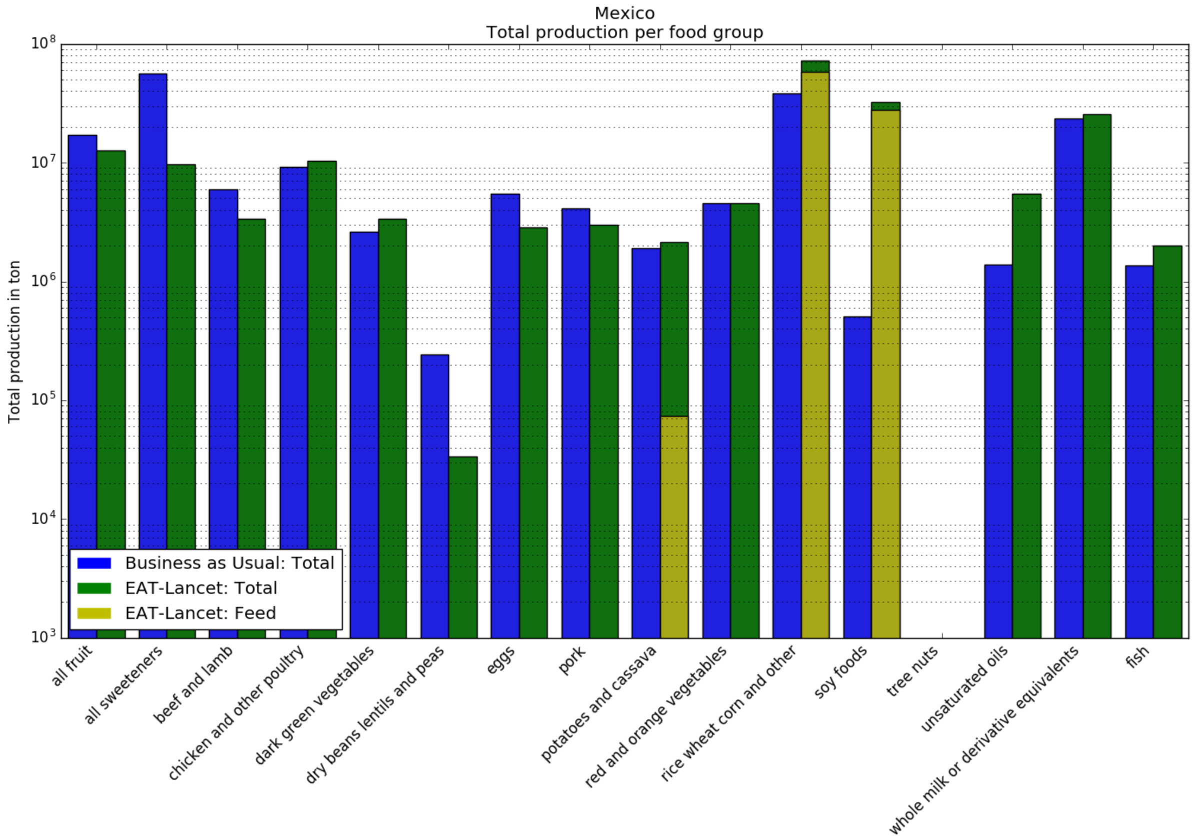

Eastern Europe
Total production per food group
Total production in ton
$10^3$
$10^4$
$10^5$
$10^6$
$10^7$
$10^8$
$10^9$
Business as Usual: Total
EAT-Lancet: Total
EAT-Lancet: Feed
all fruit
all sweeteners
beef and lamb
chicken and other poultry
dark green vegetables
dry beans lentils and peas
eggs
pork
potatoes and cassava
red and orange vegetables
rice wheat corn and other
soy foods
tree nuts
unsaturated oils
whole milk or derivative equivalents
fish

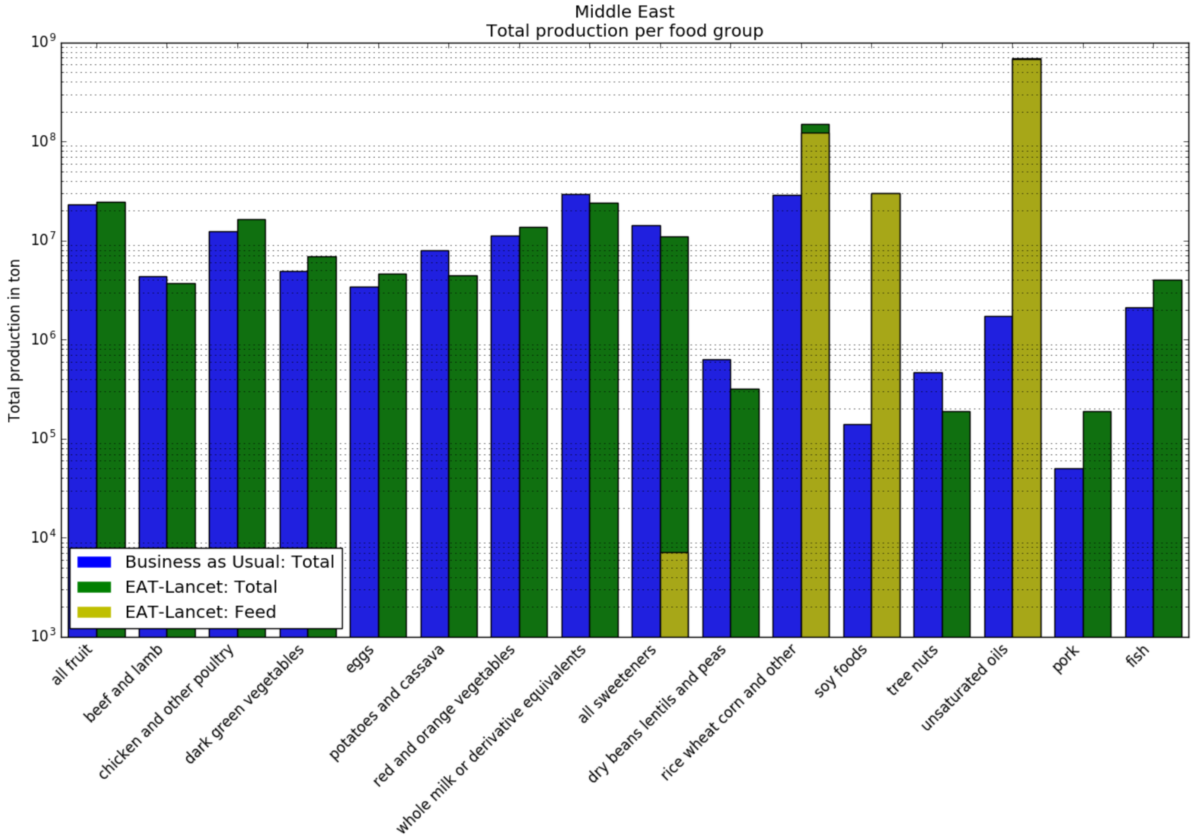

India
Total production per food group
Total production in ton
$10^3$
$10^4$
$10^5$
$10^6$
$10^7$
$10^8$
$10^9$
Business as Usual: Total
EAT-Lancet: Total
EAT-Lancet: Feed
all fruit
all sweeteners
beef and lamb
chicken and other poultry
dark green vegetables
dry beans lentils and peas
eggs
pork
potatoes and cassava
red and orange vegetables
rice wheat corn and other
soy foods
unsaturated oils
whole milk or derivative equivalents
fish

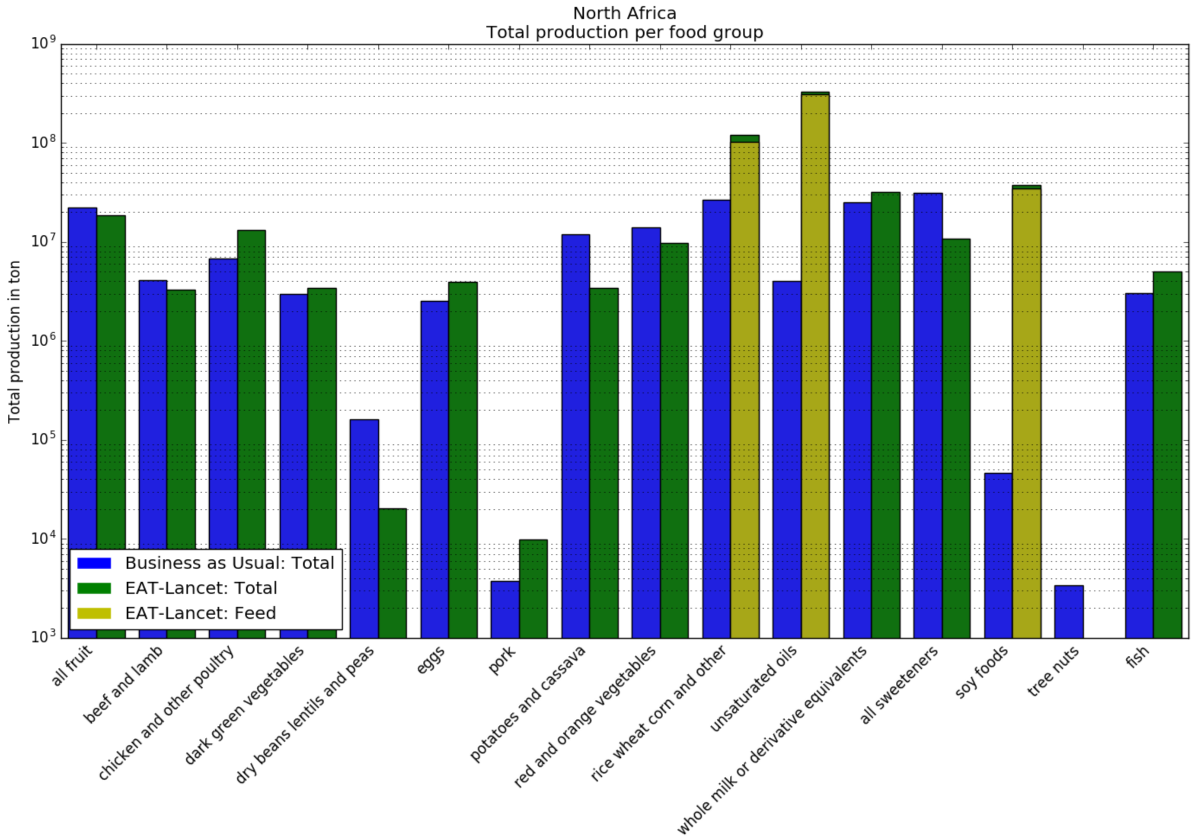

Indonesia
Total production per food group
Total production in ton
Business as Usual: Total
EAT-Lancet: Total
EAT-Lancet: Feed
all fruit
all sweeteners
beef and lamb
chicken and other poultry
dark green vegetables
eggs
pork
potatoes and cassava
red and orange vegetables
rice wheat corn and other
soy foods
unsaturated oils
whole milk or derivative equivalents
fish

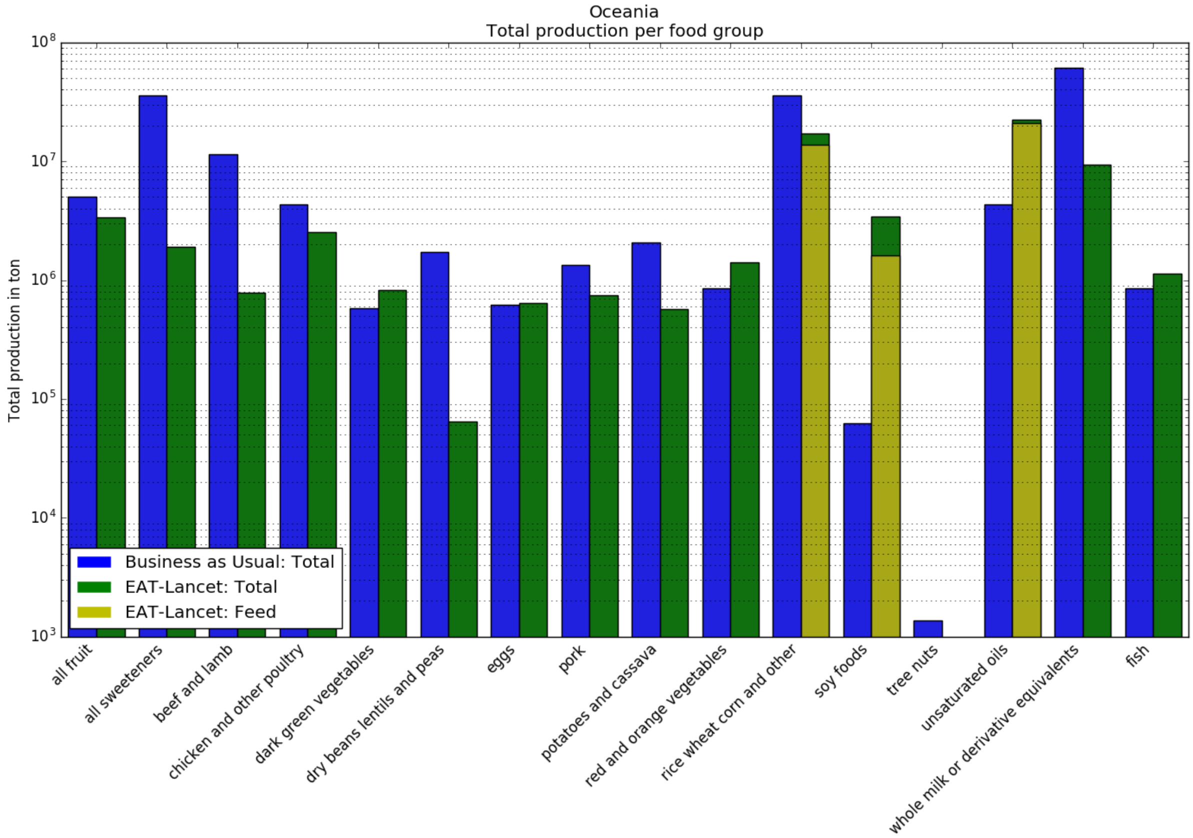

Japan
Total production per food group
Total production in ton
Business as Usual: Total
EAT-Lancet: Total
EAT-Lancet: Feed
all fruit
all sweeteners
beef and lamb
chicken and other poultry
dark green vegetables
eggs
pork
potatoes and cassava
red and orange vegetables
rice wheat corn and other
soy foods
tree nuts
unsaturated oils
whole milk or derivative equivalents
fish

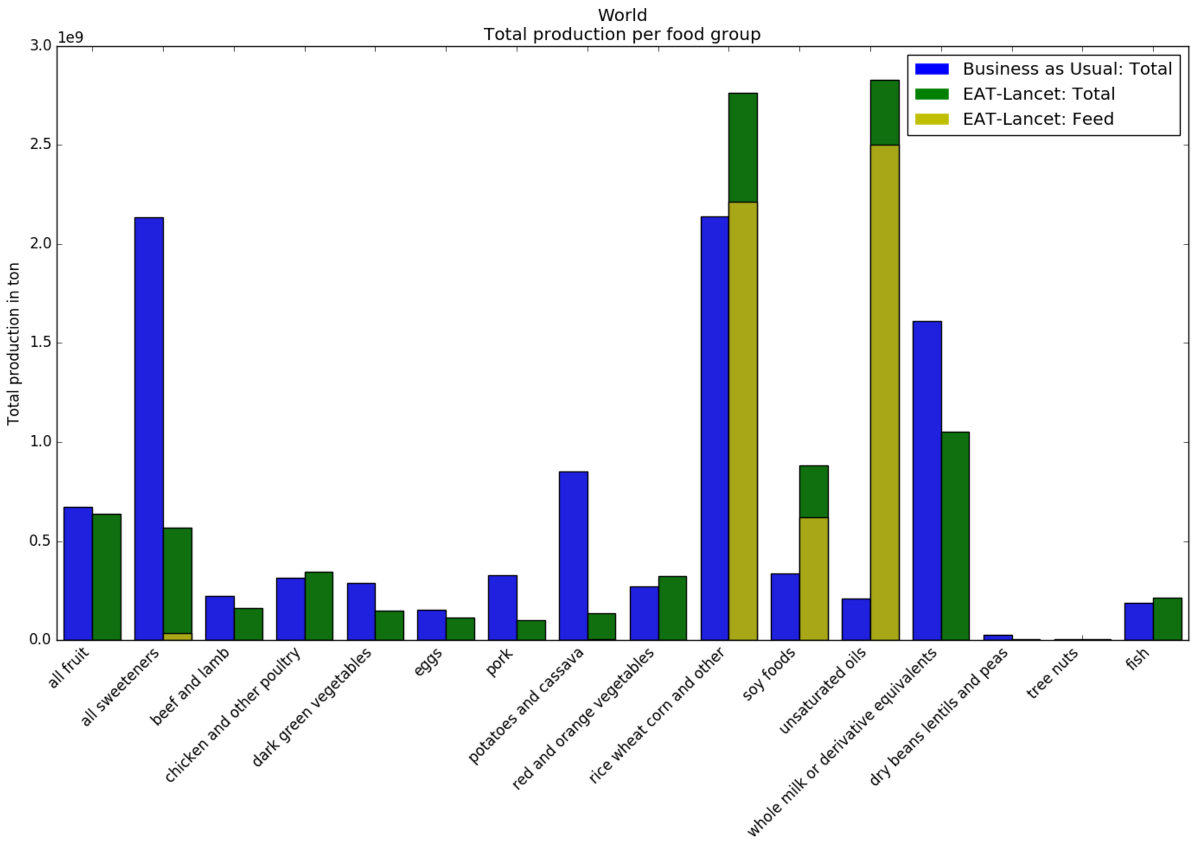

Korea
Total production per food group
Total production in ton
Business as Usual: Total
EAT-Lancet: Total
EAT-Lancet: Feed
all fruit
beef and lamb
chicken and other poultry
dark green vegetables
eggs
pork
potatoes and cassava
red and orange vegetables
rice wheat corn and other
soy foods
tree nuts
whole milk or derivative equivalents
all sweeteners
unsaturated oils
fish

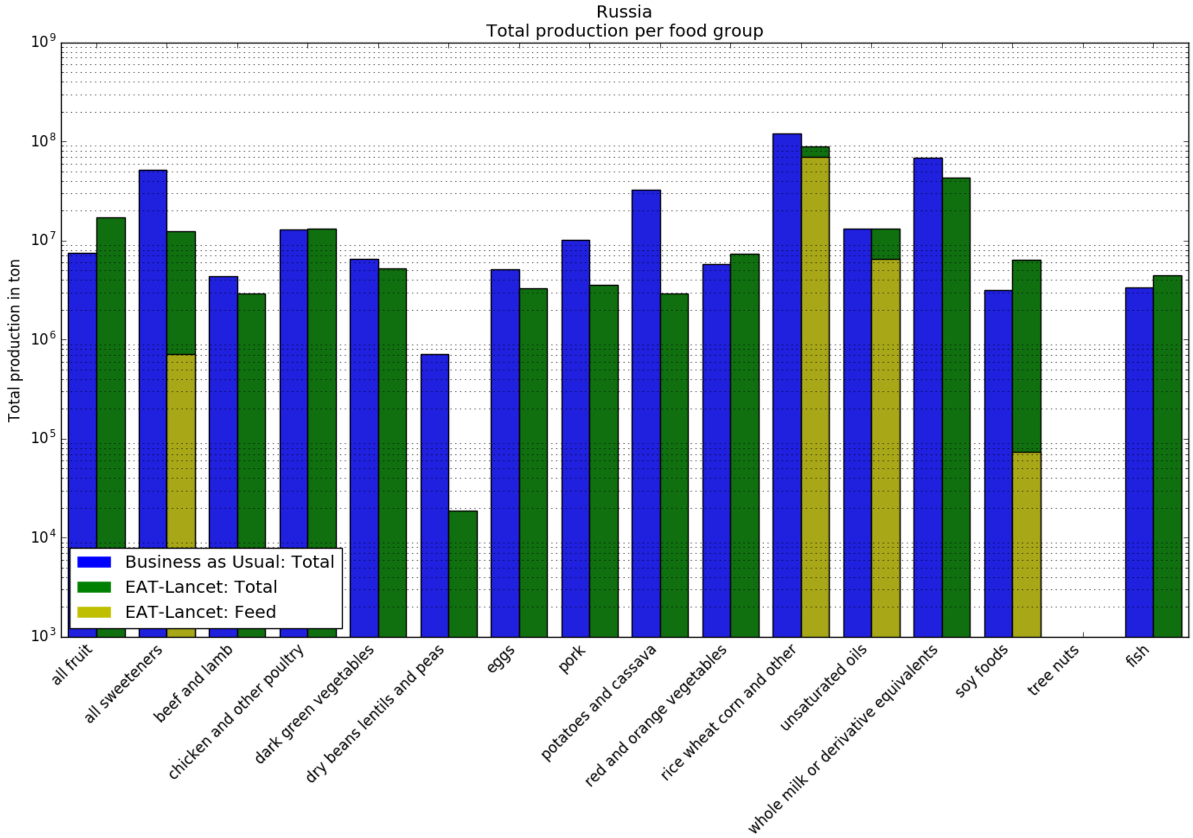

Mexico
Total production per food group
Total production in ton
Business as Usual: Total
EAT-Lancet: Total
EAT-Lancet: Feed
all fruit
all sweeteners
beef and lamb
chicken and other poultry
dark green vegetables
dry beans lentils and peas
eggs
pork
potatoes and cassava
red and orange vegetables
rice wheat corn and other
soy foods
tree nuts
unsaturated oils
whole milk or derivative equivalents
fish

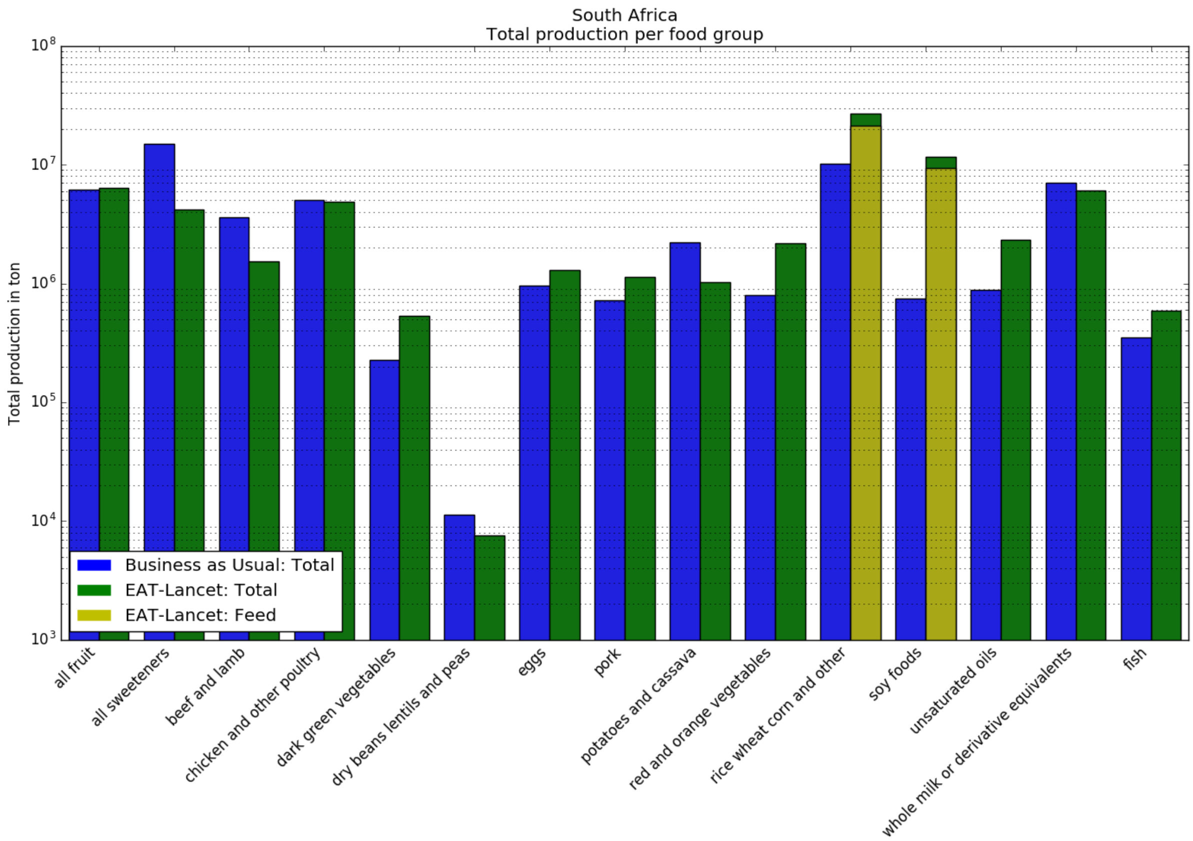

Middle East
Total production per food group
Total production in ton
Business as Usual: Total
EAT-Lancet: Total
EAT-Lancet: Feed
all fruit
beef and lamb
chicken and other poultry
dark green vegetables
eggs
potatoes and cassava
red and orange vegetables
whole milk or derivative equivalents
all sweeteners
dry beans lentils and peas
rice wheat corn and other
soy foods
tree nuts
unsaturated oils
pork
fish

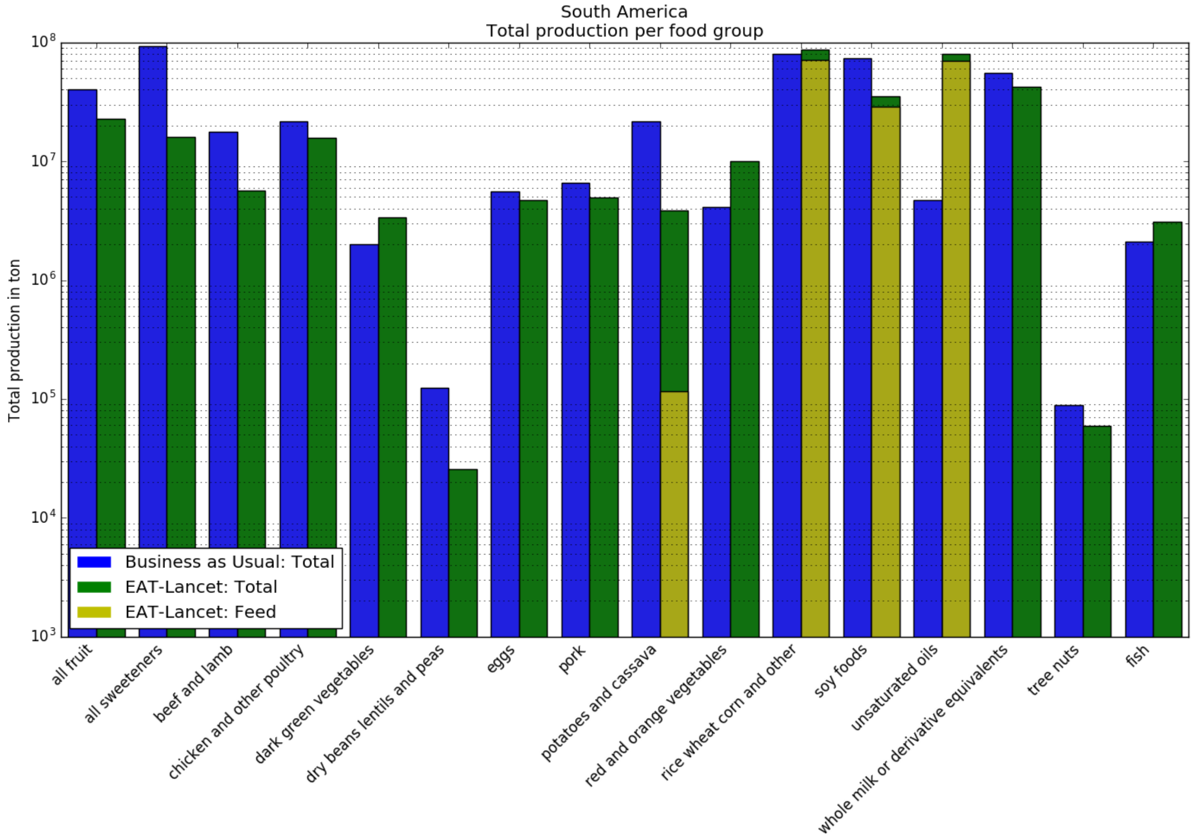

North Africa
Total production per food group
Total production in ton
Business as Usual: Total
EAT-Lancet: Total
EAT-Lancet: Feed
all fruit
beef and lamb
chicken and other poultry
dark green vegetables
dry beans lentils and peas
eggs
pork
potatoes and cassava
red and orange vegetables
rice wheat corn and other
unsaturated oils
whole milk or derivative equivalents
all sweeteners
soy foods
tree nuts
fish

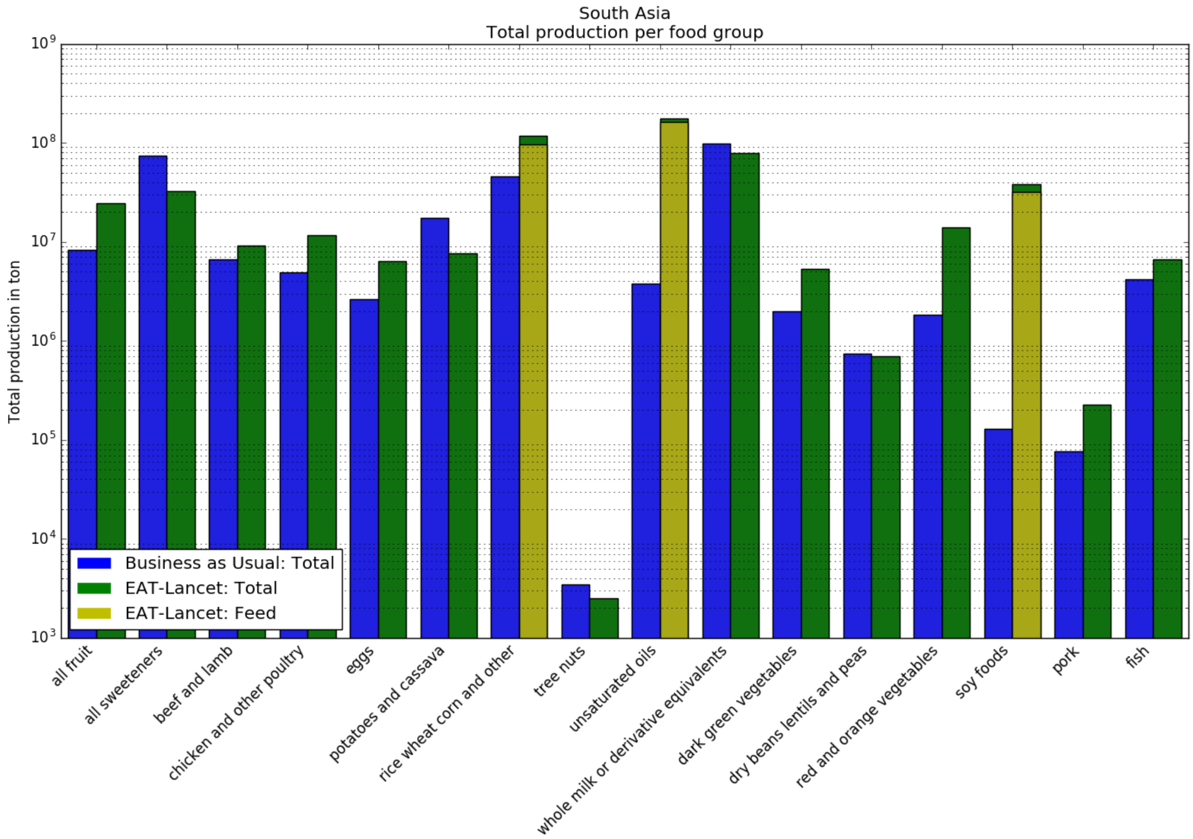

Oceania
Total production per food group
Total production in ton
$10^8$
$10^7$
$10^6$
$10^5$
$10^4$
$10^3$
Business as Usual: Total
EAT-Lancet: Total
EAT-Lancet: Feed
all fruit
all sweeteners
beef and lamb
chicken and other poultry
dark green vegetables
dry beans lentils and peas
eggs
pork
potatoes and cassava
red and orange vegetables
rice wheat corn and other
soy foods
tree nuts
unsaturated oils
whole milk or derivative equivalents
fish

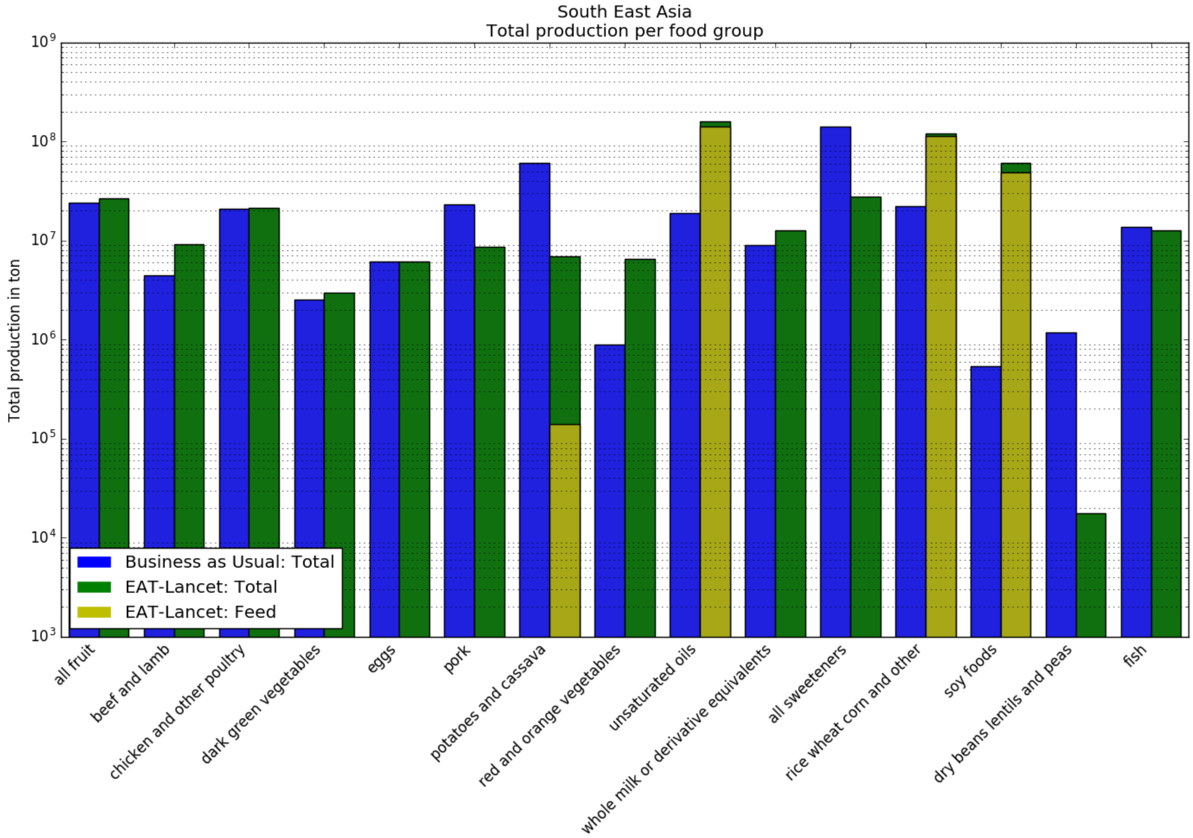

World
Total production per food group
1e9
Total production in ton
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Business as Usual: Total
EAT-Lancet: Total
EAT-Lancet: Feed
all fruit
all sweeteners
beef and lamb
chicken and other poultry
dark green vegetables
eggs
pork
potatoes and cassava
red and orange vegetables
rice wheat corn and other
soy foods
unsaturated oils
whole milk or derivative equivalents
dry beans lentils and peas
tree nuts
fish

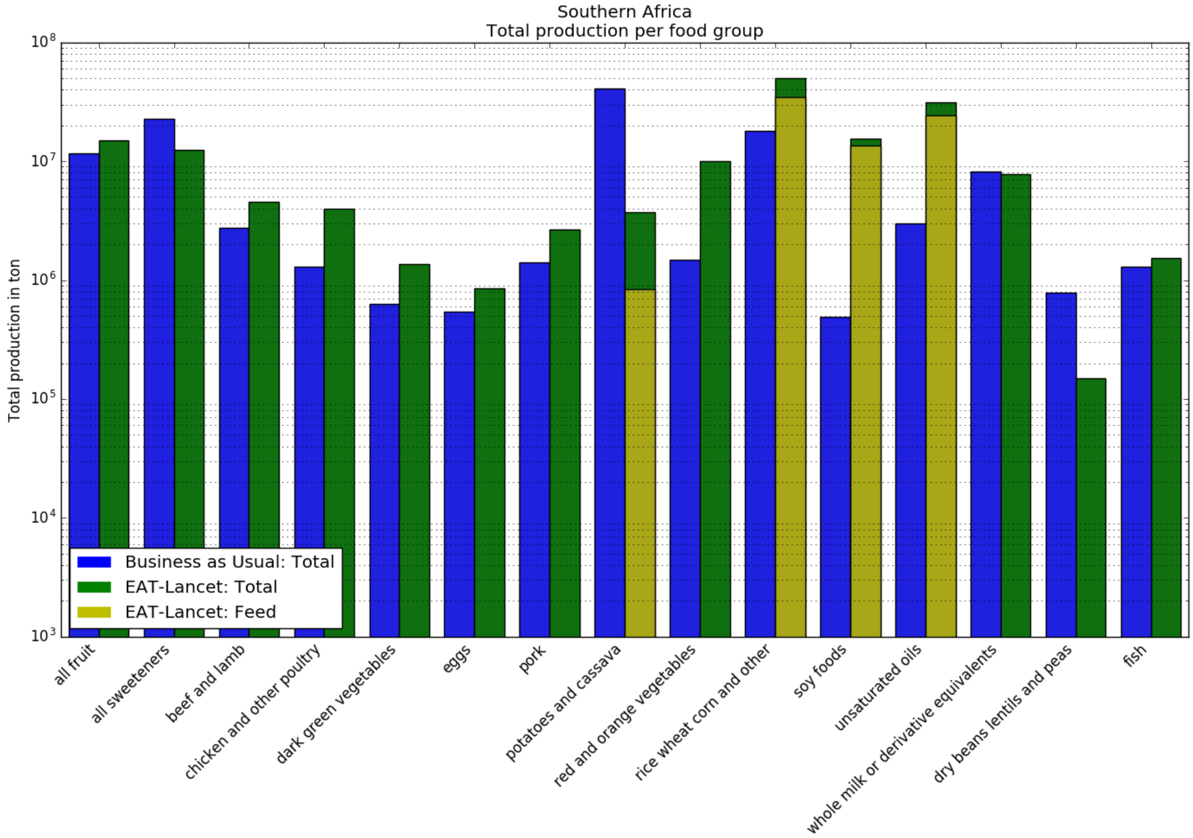

Russia
Total production per food group
Total production in ton
Business as Usual: Total
EAT-Lancet: Total
EAT-Lancet: Feed
all fruit
all sweeteners
beef and lamb
chicken and other poultry
dark green vegetables
dry beans lentils and peas
eggs
pork
potatoes and cassava
red and orange vegetables
rice wheat corn and other
unsaturated oils
whole milk or derivative equivalents
soy foods
tree nuts
fish

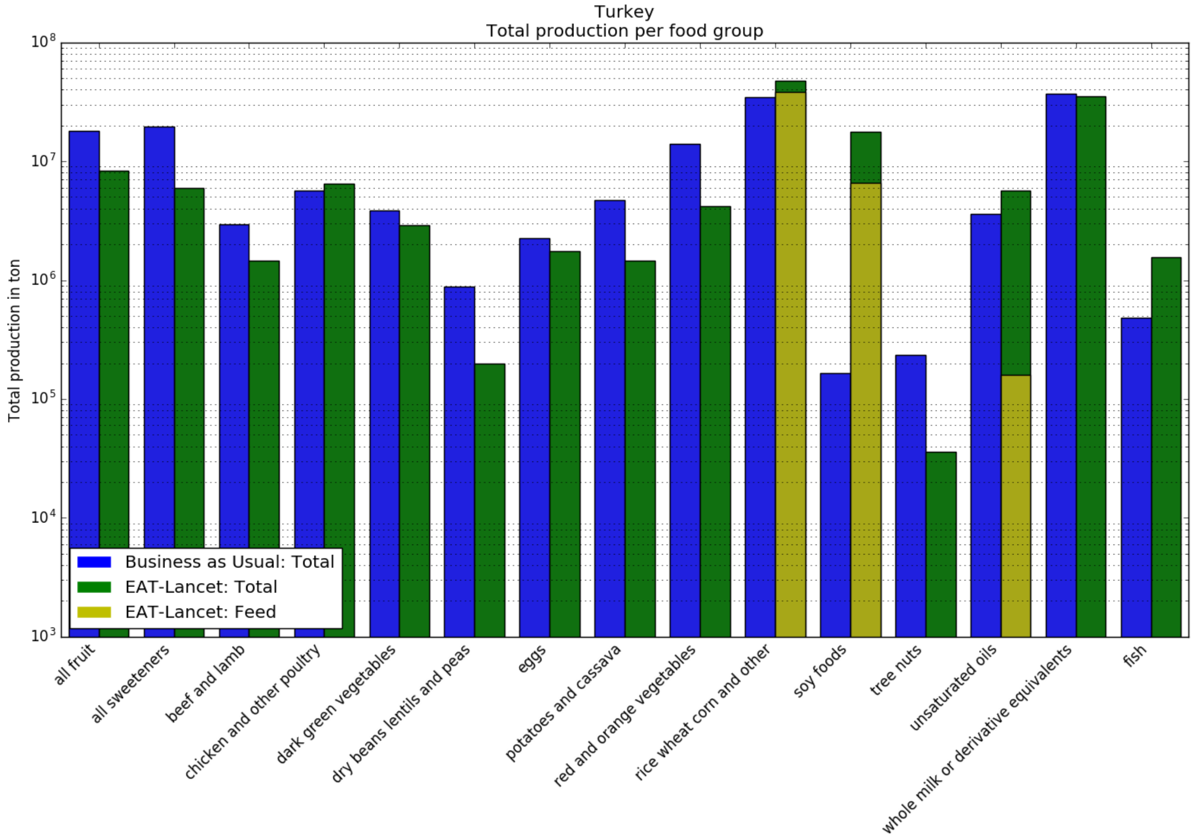

South Africa
Total production per food group
Total production in ton
Business as Usual: Total
EAT-Lancet: Total
EAT-Lancet: Feed
all fruit
all sweeteners
beef and lamb
chicken and other poultry
dark green vegetables
dry beans lentils and peas
eggs
pork
potatoes and cassava
red and orange vegetables
rice wheat corn and other
soy foods
unsaturated oils
whole milk or derivative equivalents
fish

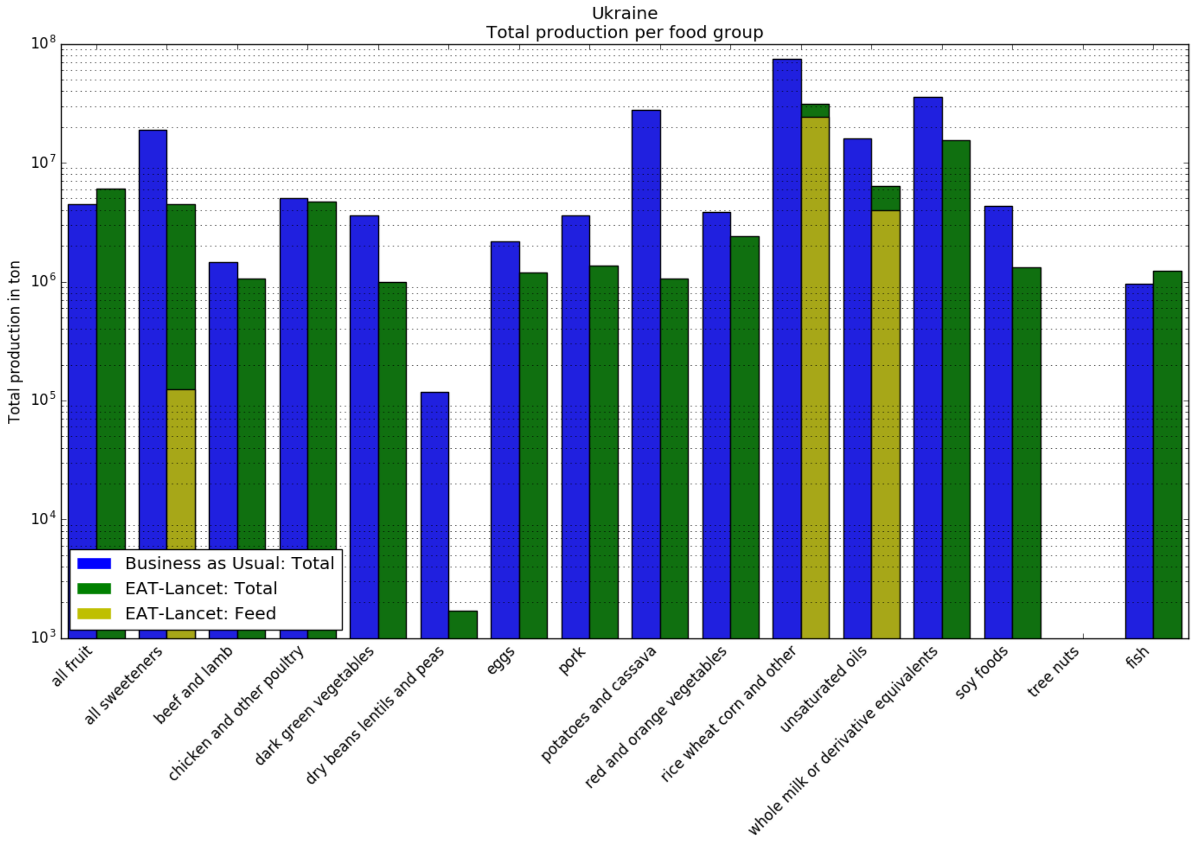

South America
Total production per food group
Total production in ton
$10^3$
$10^4$
$10^5$
$10^6$
$10^7$
$10^8$
Business as Usual: Total
EAT-Lancet: Total
EAT-Lancet: Feed
all fruit
all sweeteners
beef and lamb
chicken and other poultry
dark green vegetables
dry beans lentils and peas
eggs
pork
potatoes and cassava
red and orange vegetables
rice wheat corn and other
soy foods
unsaturated oils
whole milk or derivative equivalents
tree nuts
fish

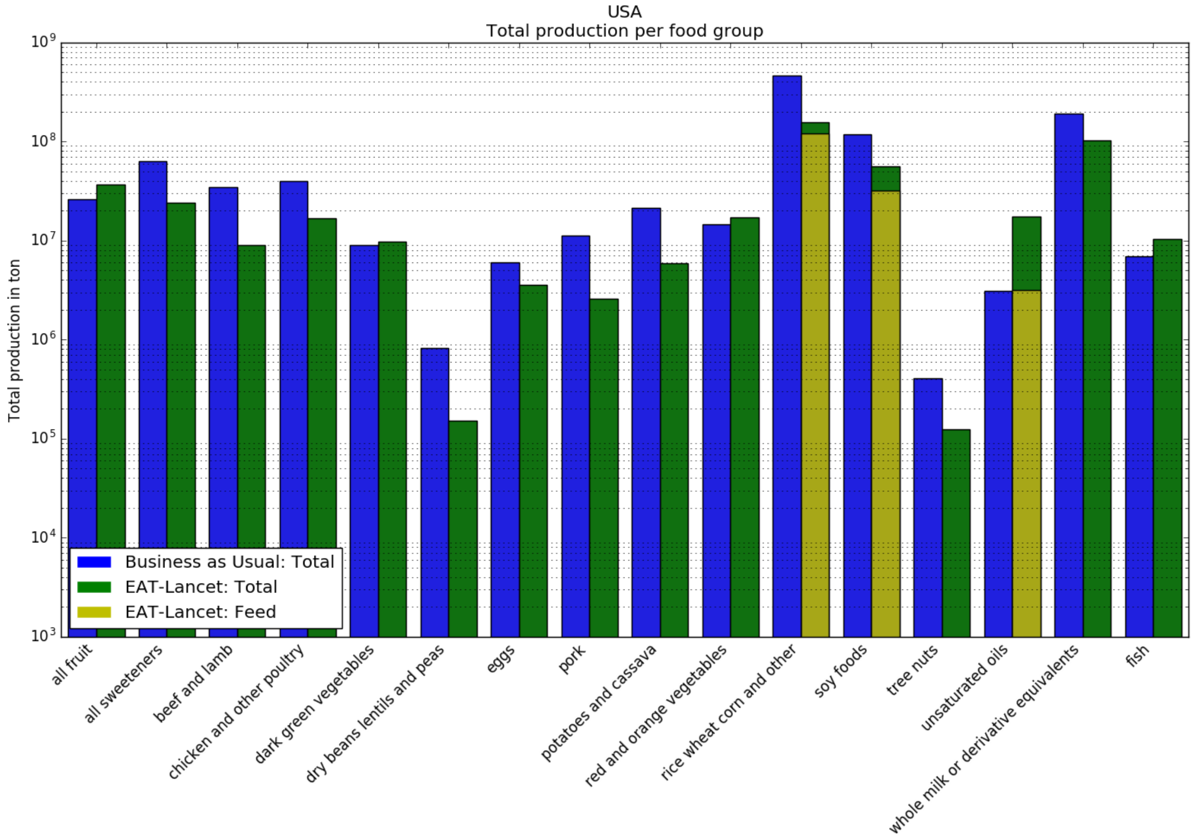

South Asia
Total production per food group
Total production in ton
$10^3$
$10^4$
$10^5$
$10^6$
$10^7$
$10^8$
$10^9$
Business as Usual: Total
EAT-Lancet: Total
EAT-Lancet: Feed
all fruit
all sweeteners
beef and lamb
chicken and other poultry
eggs
potatoes and cassava
rice wheat corn and other
tree nuts
unsaturated oils
whole milk or derivative equivalents
dark green vegetables
dry beans lentils and peas
red and orange vegetables
soy foods
pork
fish


South East Asia
Total production per food group
Total production in ton
Business as Usual: Total
EAT-Lancet: Total
EAT-Lancet: Feed
all fruit
beef and lamb
chicken and other poultry
dark green vegetables
eggs
pork
potatoes and cassava
red and orange vegetables
unsaturated oils
whole milk or derivative equivalents
all sweeteners
rice wheat corn and other
soy foods
dry beans lentils and peas
fish

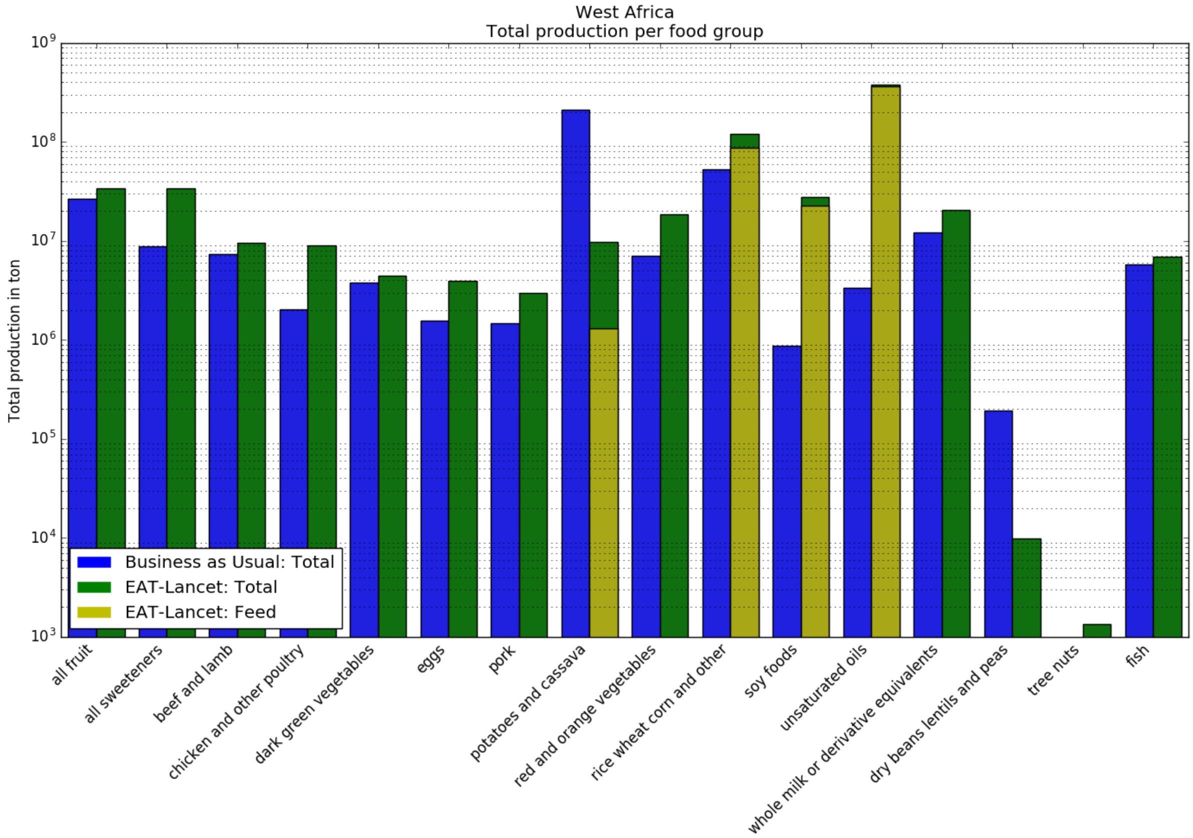

Southern Africa
Total production per food group
Total production in ton
Business as Usual: Total
EAT-Lancet: Total
EAT-Lancet: Feed
all fruit
all sweeteners
beef and lamb
chicken and other poultry
dark green vegetables
eggs
pork
potatoes and cassava
red and orange vegetables
rice wheat corn and other
soy foods
unsaturated oils
whole milk or derivative equivalents
dry beans lentils and peas
fish


Turkey
Total production per food group
Total production in ton
10^8
10^7
10^6
10^5
10^4
10^3
Business as Usual: Total
EAT-Lancet: Total
EAT-Lancet: Feed
all fruit
all sweeteners
beef and lamb
chicken and other poultry
dark green vegetables
dry beans lentils and peas
eggs
potatoes and cassava
red and orange vegetables
rice wheat corn and other
soy foods
tree nuts
unsaturated oils
whole milk or derivative equivalents
fish


Ukraine
Total production per food group
Total production in ton
10^8
10^7
10^6
10^5
10^4
10^3
Business as Usual: Total
EAT-Lancet: Total
EAT-Lancet: Feed
all fruit
all sweeteners
beef and lamb
chicken and other poultry
dark green vegetables
dry beans lentils and peas
eggs
pork
potatoes and cassava
red and orange vegetables
rice wheat corn and other
unsaturated oils
whole milk or derivative equivalents
soy foods
tree nuts
fish



USA
Total production per food group
Total production in ton
Business as Usual: Total
EAT-Lancet: Total
EAT-Lancet: Feed
all fruit
all sweeteners
beef and lamb
chicken and other poultry
dark green vegetables
dry beans lentils and peas
eggs
pork
potatoes and cassava
red and orange vegetables
rice wheat corn and other
soy foods
tree nuts
unsaturated oils
whole milk or derivative equivalents
fish

West Africa
Total production per food group
Total production in ton
Business as Usual: Total
EAT-Lancet: Total
EAT-Lancet: Feed
all fruit
all sweeteners
beef and lamb
chicken and other poultry
dark green vegetables
eggs
pork
potatoes and cassava
red and orange vegetables
rice wheat corn and other
soy foods
unsaturated oils
whole milk or derivative equivalents
dry beans lentils and peas
tree nuts
fish