Assessing self-sufficiency: analyzing the gap between national food production and food-based dietary guidance

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Abstract

In light of increasing nationalist trends, recent disruptions to global food supply chains, and efforts to concurrently promote sustainable diets, we utilize the World Wildlife Fund's (WWF) Livewell report to assess national food self-sufficiency. We observed that one in three countries cannot meet self-sufficiency for more than two of the seven essential food groups. This underscores significant inter-regional trade reliance, notably in the Caribbean, West Africa, and Gulf states.

Main

Striving for self-sufficiency in a globalized food economy

Dietary change, population growth, and climate change are putting increasing pressure on our global food systems[1–3]. A growing world population and a dietary shift towards more resource-intensive foods lead to an increasing food demand[2,3]. Meeting this demand necessitates an increase in global food production, a task complicated by the fact that planetary resources are already partially overexploited[1] and an increase in extreme weather events[4] is impairing crop production[5].

In recent decades, globalization accompanied by a surge in international trade has led to spatial separation of production and consumption[6]. On the one hand, this enhanced the efficiency of production systems[7]. On the other hand, this allocation has led to a less diverse domestic food production structure through specialization[8]. While gains from trade are often unequally distributed, losers have been insufficiently compensated[9–11]. Consequently, the negative impacts of globalized supply chains have recently fueled (economic) nationalism[9–13]. This ignited discussions on food sovereignty[14,15] and reinforced local food movements to reduce dependence on globalized food value chains[15–19].

Recently, discussions about shortening food supply chains have become more frequent, driven by both food security and environmental considerations. Heavy reliance on long supply chains also increases susceptibility to market shocks[20], as the recent disruptions during the COVID-19 pandemic[21,22] and the outbreak of the war in Ukraine[23–25] have shown. These disruptions posed significant threats to global food security[21,23,26], exacerbated by export bans in other producer countries like Indonesia (palm oil) and India (wheat). These scenarios have prompted discussions on bolstering autonomy and self-sufficiency in food supply systems to enhance resilience and reduce dependence on long-haul transportation and world market prices[27]. Additionally, given that food systems contribute to a third of all emissions[28], the "eat local" mantra is widely advocated to reduce the carbon footprint of diets, even though transport contributes to only around five percent of these emissions[28].

This raises the question of whether countries can be food self-sufficient. We use FAO Food Balance Sheets (FBS) 2020 production data and the consumption guidelines from the WWF's Livewell diet[29] to analyze the discrepancy between national food availability from domestic production and food-based dietary guidance at various regional levels across seven food groups.

Caloric self-sufficiency has been assessed at various administrative levels based on total food production and current consumption patterns[30]. Kinnunen et al.[31] calculate the minimum distance required to meet the food demand for cereals, maize, rice, and roots. In contrast to these studies, we define food self-sufficiency as meeting food needs according to the Livewell and EAT-Lancet

dietary guidance rather than current demand. We pursue a holistic approach, examining various food groups rather than focusing solely on calories, individual crops, or specific food categories.

Country-level food self-sufficiency

Out of 184 countries, 154 can fulfill the requirements for two to five out of seven food groups of the Livewell diet through their domestic production. Four countries—Guyana, Türkiye, Uzbekistan, and Vietnam—achieve self-sufficiency in six out of seven food groups. However, no country covers all food groups independently. In contrast, eight countries, primarily situated in the Middle East—Afghanistan, United Arab Emirates, Djibouti, Iraq, Lesotho, China Macao SAR, Qatar, and Yemen—cannot satisfy the needs of any food group with their domestic production. Notably, almost one out of three countries can only meet self-sufficiency requirements for two or fewer out of the seven food groups. Of these countries, 21 are in Africa, 10 in the Caribbean, and 5 in Europe. Only one in four countries achieve self-sufficiency in five or more food groups, and almost half (40%) of these countries are in Europe and 19% in South America.

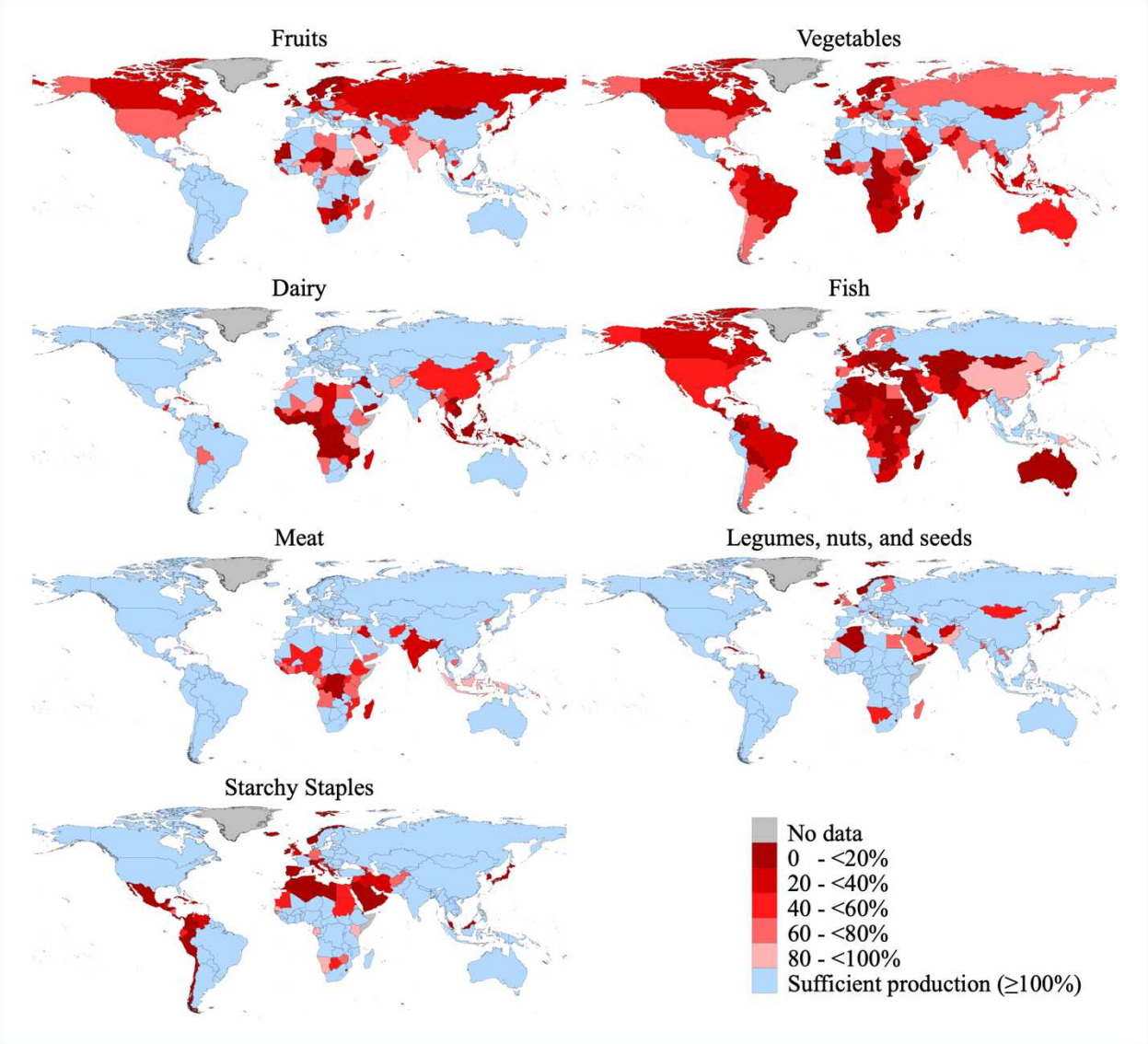

Figure 1. Percentage of self-sufficiency for specific food groups. This figure shows national food availability from domestic production as proportion from recommended intake by the Livewell diet in grams per capita per day for 184 countries in 2020. Thereby, 100% means that all recommendations of a food group are met.

A relatively high degree of self-sufficiency is achieved for legumes, nuts, and seeds (70% of countries) and meat (66%) (Figure 1). Approximately half of the countries can independently meet their needs for dairy (48%), starchy staples (45%), and fruits (46%). In contrast, less than one in four countries achieve self-sufficiency for fish (22%) and vegetables (24%).

All countries in South America and three out of four countries in the Caribbean are self-sufficient in fruits. On the contrary, two-thirds of European and Asian countries fall short in fruit self-sufficiency. In Northern Europe, all countries (n=10) are unable to cover even half of their needs for fruit.

The region demonstrating particularly high self-sufficiency in vegetables is the Mediterranean and Central Asia. However, 84% of the countries in sub-Saharan Africa produce insufficient vegetables. One in three countries with less than half of their vegetable needs met is in Africa. Again, all ten Northern European countries fall into this category, unable to fulfill their vegetable requirements with their own production. Except for Guyana, no country in South America and the Caribbean is self-sufficient in vegetables. In Oceania, only New Zealand can meet their vegetable needs.

Most African countries (84%) fail to meet their dairy product needs, with 66% not able to meet even half of the requirements. A similar pattern is observed in Oceania, where 83% of countries cannot cover half of their requirements to be self-sufficient (only Australia and New Zealand are self-sufficient). Conversely, every single European country can meet its dairy needs independently. In South America, only Bolivia and Suriname produce insufficient dairy to meet their needs.

Domestic production of fish and seafood falls substantially short of meeting domestic needs. All regions except for Oceania struggle with self-sufficiency for fish. No more than 22% of countries globally can satisfy their needs with their production. In most cases, there is a severe deficit in

production. A total of 116 (63%) countries cannot cover half of their self-sufficiency needs, 91 (49.46%) not even a quarter.

Two-thirds of all countries across the world produce sufficient meat to cover their needs. A total of 78 (43%) countries produce more than twice as much domestically as their needs. However, especially in sub-Saharan Africa, countries produce insufficiently. Notably, two out of three countries in Africa do not produce enough meat to be self-sufficient, representing half of the countries globally. In Oceania, this figure stands at 50%. In Europe, all countries except North Macedonia can meet their meat requirements with their domestic production.

When examining self-sufficiency in starchy staples, three regions become apparent where there are insufficient production levels: the Mediterranean region, the Arabian Peninsula, and Central/West America. In the Americas, 25 out of 35 countries do not produce enough starchy staples to achieve self-sufficiency. This is particularly evident in the Caribbean, where 12 out of 13 countries face this challenge (Dominica is the exception). Similarly, in the Middle East, 14 out of 15 countries fall short where only Türkiye produces enough starchy staples to satisfy their needs.

Regional self-sufficiency and trade dynamics

We also explored self-sufficiency at different regional levels. The level of self-sufficiency within economic unions (Table 1) echoes patterns observed at the country level. For instance, the Gulf Cooperation Council (GCC), consisting of Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates, is only self-sufficient in meat and dairy production. Similarly, the West African Economic and Monetary Union (WAEMU) and the Caribbean Community (CARICOM)

are self-sufficient in only two food groups each—legumes, nuts, and seeds, and starchy staples for WAEMU, and fruits and meat for CARICOM. While many economic unions achieve self-sufficiency for five out of seven food groups, none exceed this threshold. No union is self-sufficient for vegetables, and only two achieve this for fish and seafood. Meat requirements are met by all economic unions except three in West and East Africa and South Asia.

Table 1. Percentage of self-sufficiency for specific food groups at different regional levels.

Economic Union	Legumes, nuts and seeds	Starchy staples	Dairy products	Fish and fish products	Fruits	Meat and meat products	Vegetables	# of groups ≥ 100%
AFTA	3638	195	15	177	121	181	61	5
CACM	1254	11	144	2	354	201	63	4
CAN	803	25	154	210	289	299	45	5
CARICOM	87	41	32	30	145	121	34	2
CEMAC	740	157	20	43	171	149	57	4
EAC	348	160	95	32	173	62	45	3
EACU	860	287	373	92	38	397	87	4
EUCU+UK	533	59	522	9	135	491	79	4
GCC	28	0	101	-5	62	150	37	2
MERCOSUR	4851	299	288	31	201	751	44	5
SAARC	284	153	215	38	79	41	69	3
SACU	236	136	105	55	158	323	36	5
USMCA	2203	165	355	45	101	620	77	5
WAEMU	825	179	40	29	76	84	82	2

Notes: European Union Customs Union and United Kingdom (EUCU+UK), Eurasian Customs Union (EACU), East African Community (EAC), West African Economic and Monetary Union (WAEMU), Southern African Customs Union (SACU), Communauté Économique et Monétaire de l'Afrique Centrale (CEMAC), Mercosur, Andean Community (CAN), Caribbean Community (CARICOM), Central American Common Market (CACM), Gulf Cooperation Council (GCC), ASEAN Free Trade Area (AFTA), United States-Mexico-Canada Agreement (USMCA), South Asian Association for Regional Cooperation (SAARC). The numbers are the proportion of domestic production (deducted by food that will not enter the body) of nutritional requirements of the Livewell diet in percentage. Thereby, 100% means the requirements of the respective food group are met.

The importance of trade in achieving nutritional goals

By enabling trade at various regional levels, countries with surplus food production can help meet the shortfalls in neighboring countries. Thus, broadening the scope of trade can lead to substantial

improvements in self-sufficiency. In this section, we delve deeper into the magnitude of these improvements at different regional levels.

When countries engage in intra-union trade, it leads to an average improvement in self-sufficiency of 0.25 food groups. Notably, Lesotho stands out as a major beneficiary of intra-customs trade, with an increase of five food groups in their self-sufficiency. When we consider trade on the UN world region level, the impact is even more striking. On average, self-sufficiency improves by 1.42 food groups. When we align our findings with nutrient availability, considering current trade dynamics, notable similarities emerge, especially concerning less tradable food items[32]. The perishable nature of meat and, particularly, dairy products may contribute to diminished nutrient availability from essential micronutrients like calcium or Vitamin B12, particularly in regions with low self-sufficiency. However, regions displaying high self-sufficiency in fruits, like Latin America, exhibit low Vitamin C availability, which is possibly linked to substantial exports.

Our findings are not specific to the use of the Livewell diet. Countries exhibit similar self-sufficiency patterns when applying the EAT-Lancet diet (SI Figure 2). In fact, countries perform even worse. Twelve countries meet the requirements for no food group and no country achieves self-sufficiency of more than five food groups. This is primarily driven by comparatively higher requirements for legumes, nuts, and seeds.

While national policymakers increasingly emphasize the importance of the consumption of domestically produced food, discussions around national independence and self-reliance in various economic sectors gain momentum. These findings underscore that when it comes to achieving

158 comprehensive nutritional goals, nations cannot stand alone. Acknowledging the detrimental
159 effects of food trade on both human[33] and planetary health[34], it is noteworthy that food transport
160 accounts for relatively little of food systems emissions[28,34]. Trade increases diversity in food
161 supply and is crucial to comprehensively meet the dietary needs of many countries and can even
162 contribute to resilience to shocks[35]. While supply of nutritious foods is insufficient to meet its
163 recommended consumption levels, resource-intensive animal-sourced foods are being
164 overproduced in many regions. This necessitates a systematic change of consumption and
165 production patterns and public policies to achieve a shift towards healthy and sustainable diets.

Online methods

Data sources

We used three main data sources for our analysis: (1) Food and Agricultural Organization (FAO) Food Balance Sheets (FBS), (2) age-specific food group intake recommendations for individuals, and (3) the United Nations (UN) World Population Prospects.

We utilize production data sourced from the FAO FBS for the year 2020. We adjust the production data by food used for feed, food that is lost throughout the food-value chain, utilization for non-food purposes, and allocation for seeding, all provided by the FAO FBS. In addition, we use data provided by Gustavsson et al. (2011) to consider the fraction of nonedible and wasted food. We divide the estimated national food supply by the population size in 2020 to per capita daily food supply in grams.

For our recommendations for seven food groups, we draw upon the World Wildlife Fund's (WWF) "Livewell diet". This diet gives per capita, per-day recommendations for 29 specific food items, tailored to four distinct age groups, designed to promote both health and sustainability (WWF Technical Report). The diet is constructed incorporating environmental impact data, in conjunction with dietary guidelines from Eatwell. The nuanced decomposition of this diet enables us to take variations in the demographic composition of countries into account which, in this case, represents an advantage over the EAT-Lancet diet. It is important to note that the guidelines in both diets align closely for adults. The diet is constructed using an optimization tool employing quadratic programming to optimize the composition of current diets to concurrently enhance nutritional and environmental outcomes.

The UN World Population Prospects provides country-level population estimates, in terms of the total population size as well as the proportion of each country's population by age. We calculate the estimated population for each age group in 2020 for which dietary recommendations are available.

Table 1. Livewell food group consumption recommendations by age group (19-64y, 1.5-3y, 4-10y, 11-18y, 65+y) in the World Wildlife Fund's 2023 technical report and EAT-Lancet food group recommendations.

Food group	Livewell diet					EAT-Lancet diet
	19-64y	1.5-3y	4-10y	11-18y	65+y	
Total meats	36.51	22.52	44.14	30.85	31.11	43
Fruits	158.58	136.21	145.03	106.89	150.37	200
Legumes/nuts/seeds	36.40	14.81	18.10	20.69	22.02	125
Dairy	147.32	297.81	109.47	189.51	210.60	250
Fish seafood	40.84	14.04	18.73	26.77	40.71	28
Starchy staples	390.60	191.35	263.75	396.65	310.59	282
Vegetables	265.81	110.18	154.97	248.32	203.73	300

All values reported as grams/day. Food group categories aggregated from the WWF Livewell food categories: **total meats** = 'beef', 'lamb', 'pork', 'offal', 'poultry', and 'processed red meat'; **fruits** = 'fruit'; **legumes nuts seeds** = 'legumes, nuts and oilseeds'; **dairy** = 'milk and milk products', 'cheese'; **fish seafood** = 'white fish', 'oily fish', 'shellfish'; **starchy staples** = 'cereal and other cereal products', 'potatoes'; **vegetables** = 'vegetables' (does not include potatoes or legumes).

Data analysis

To calculate national food supply, we divide the adjusted national production by the country's population and 365 to obtain supply per capita per day.

To compute the dietary requirements for various food groups, we start by multiplying the recommended intake for each specific age group by the population of that age group within the country. This calculation is carried out for all age groups and the results are then summed together to derive the total dietary requirements for the entire population. To obtain per capita dietary needs, we subsequently divide the national dietary requirements by the total population, encompassing individuals of all age groups. This yields the following equation, where g is the age group and c the country:

$$need_c = \frac{\sum_{g=1}^{N} recommendation_{c,g} \times population_{c,g}}{Total\ population_c}$$

The gap between national food production is then the difference between the daily intake needs in grams and the per capita supply.

Data code and availability

All data is publicly available:

- FAO FBS 2020 data are open access through FAOSTAT: https://www.fao.org/faostat/en/#data/FBS.

- UN world population estimates are available through the UN's population division: https://population.un.org/wpp/.
- Livewell food group recommended intake levels are available through the World Wildlife Fund's 2023 'Eating for Net Zero' technical report: https://www.wwf.org.uk/sites/default/files/2023-05/Eating_For_Net_Zero_Technical_Report.pdf.
- Food waste at the household and edible portions: https://www.fao.org/3/i2697e/i2697e.pdf

STATA code is available upon request.

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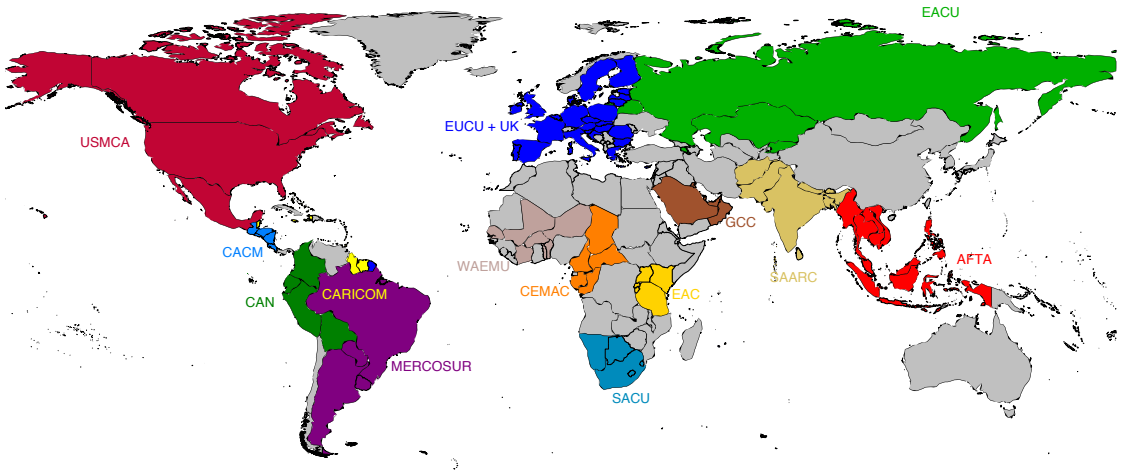
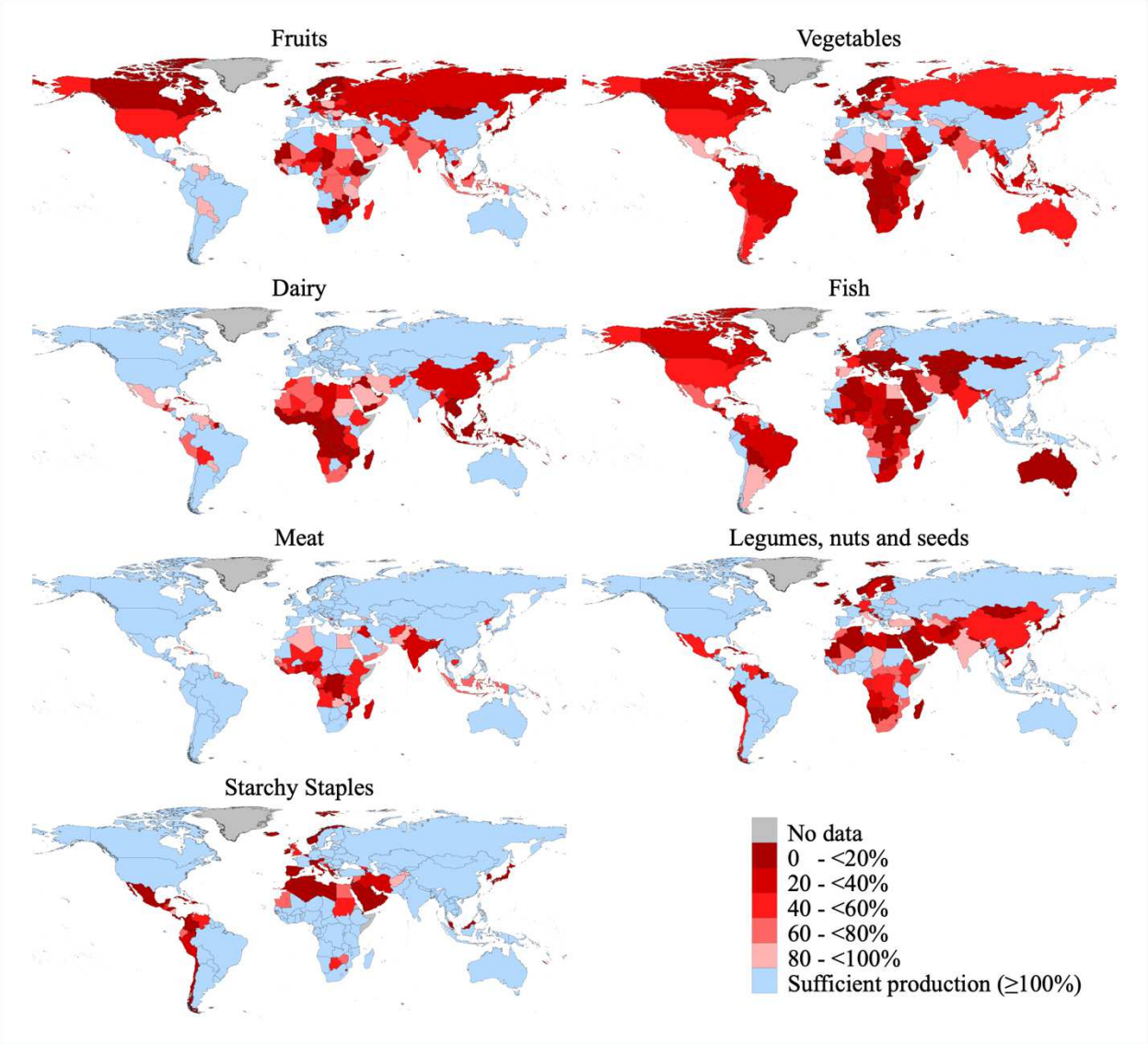
Supplementary information

SI Table 1. Assignment of countries to economic unions.

ASEAN Free Trade Area (**AFTA**)	Brunei, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam
Central American Common Market (**CACM**)	Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua
Andean Community (**CAN**)	Bolivia, Colombia, Ecuador, Peru
Caribbean Community (**CARICOM**)	Antigua and Barbuda, The Bahamas, Barbados, Belize, Dominica, Grenada, Guyana, Haiti, Jamaica, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Suriname, Trinidad and Tobago
Communauté Économique et Monétaire de l'Afrique Centrale (**CEMAC**)	Cameroon, Central African Republic, Chad, Rep. Congo, Gabon
East African Community (**EAC**)	Burundi, Kenya, Rwanda, Tanzania, Uganda
Eurasian Customs Union (**EACU**)	Armenia, Belarus, Kazakhstan, Kyrgyz Republic, Russian Federation
European Union Customs Union and United Kingdom (**EUCU+UK**)	Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, United Kingdom
Gulf Cooperation Council (**GCC**)	Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates
MERCOSUR	Argentina, Brazil, Paraguay, Uruguay
South Asian Association for Regional Cooperation (**SAARC**)	Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka
Southern African Customs Union (**SACU**)	Botswana, Eswatini, Lesotho, Namibia, South Africa
United States-Mexico-Canada Agreement (**USMCA**)	Canada, Mexico, United States
West African Economic and Monetary Union (**WAEMU**)	Benin, Burkina Faso, Côte d'Ivoire, Mali, Niger, Senegal, Togo



SI Figure 1. World map of economic unions used in this analysis.



SI Figure 2. Percentage of self-sufficiency for specific food groups according to EAT-Lancet. This figure shows national food availability from domestic production as proportion from recommended intake by the EAT-Lancet diet in grams per capita per day for 184 countries in 2020.