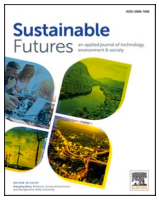
Sustainable Futures 11 (2026) 101566

Contents lists available at ScienceDirect

Sustainable Futures

journal homepage: www.sciencedirect.com/journal/sustainable-futures



A systematic literature review of factors influencing national food self-sufficiency

Christian Ritzel

Economic Modeling and Policy Analysis, Agroscope, CH-8356 Ettenhausen, Switzerland

ARTICLE INFO

Keywords:
Food security
Protectionism
Developing countries
Sustainable diets
Global shocks

ABSTRACT

Global shocks, such as the COVID-19 pandemic and the war in Ukraine, have put food self-sufficiency (i.e., the ratio between domestic production and domestic consumption) back on the political agenda in heavily food importing countries. To extract current insights into this key aspect of food security, this study aimed to identify the factors affecting food self-sufficiency and the actors and actions that influence these factors. Our research focused on actors and actions that promote sustainable development and food self-sufficiency. Here, we conducted a systematic literature review on the factors influencing national food self-sufficiency. Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines, 92 scientific studies were identified. Using inductive coding, individual factors, such as climate change, agricultural land, population, plant-based diet, and protectionism, were grouped into external events, agricultural inputs, macroeconomic factors, dietary habits, trade and agricultural policies, urbanization, alternative agricultural production systems, and food waste and losses. Using the approach of multi-actor constellations, we also identified actors and actions that can influence these factors. The findings showed that beyond the responsibility of policymakers to develop institutional frameworks for promoting food self-sufficiency, the intensification of agricultural production and a change in consumer behavior toward a more sustainable diet, among other factors, had a positive impact on food self-sufficiency. However, a closer look revealed that the intensification of agricultural production had adverse impacts on the environment, highlighting the need for a sustainable intensification. Changing consumer behavior toward a plant-based diet was associated with positive impacts on the environment.

1. Introduction

According to the Food and Agriculture Organization [56], food security at the country level is achieved when food is available, accessible, and nutritious and when food availability and accessibility are stable at all times. Food self-sufficiency (FSS) refers to the availability dimension of food security by focusing on the domestic capacity to produce food in sufficient quantities for domestic consumption [40]. FSS is an important aspect of ensuring food security, especially in developing countries, where undernourishment is a major problem [4,121]. Although neoliberal economic policies promoted trade liberalization between the 1980s and the early 2000s, global shocks, such as the 2007–2008 food price crisis or supply chain disruptions due to the COVID-19 pandemic and the war in Ukraine, have put food security and FSS back on the political agenda in import-dependent developed and developing countries [38,146]. For example, 76.3 % of the cereal supply in Northern and Western Africa came from imports in 2020 [63]. The war in Ukraine has therefore threatened the food supply in these regions because they were heavily dependent on cereal and fertilizer imports from Russia and the Ukraine [59]. The fragile nutritional status of children prior to the conflict was expected to worsen due to rising food prices [132].

Against this background, if a high FSS is considered a strategy for reducing vulnerability to global shocks [147] and contributing to Sustainable Development Goal 2, "Zero Hunger" [129] two components of FSS can be addressed: domestic production and domestic consumption. FSS can be expressed as the ratio between domestic production and domestic consumption (i.e., the FSS ratio) [79]. A country's FSS can take one of three states [37]. First, domestic production is equal to domestic consumption (i.e., FSS ratio = 100 %). Second, domestic production is larger than domestic consumption, indicating a production surplus and a potential for export (i.e., FSS ratio > 100 %). Third, domestic production is lower than domestic consumption, indicating a production deficit and a need to import (i.e., FSS ratio < 100 %). In the European Union (EU), for example, production exceeds consumption for most animal-based products (e.g., butter, cheese, beef, and pig meat), while production is lower than consumption for a variety of plant-based products (e.g.,

E-mail address: christian.ritzel@agroscope.admin.ch.

https://doi.org/10.1016/j.sftr.2025.101566
Received 5 May 2025; Received in revised form 25 November 2025; Accepted 27 November 2025
Available online 4 December 2025

oilseeds, protein crops, sugar, and maize) [52].

The aim of this study is fivefold. First, we aim to identify the factors affecting the two components of FSS (i.e., domestic production and domestic consumption) at the country level and their direction of effect (i.e., positive, negative, or mixed). Second, we aim to develop a framework based on the individual factors that affect FSS. Third, we aim to demonstrate geographical heterogeneity in factors affecting FSS. Fourth, we aim to identify the factors that can (or cannot) be changed, the actors who can change the factors, and their actions. In this context, we aim to analyze which factors and actions promote sustainable development and FSS. Fifth, we aim to discuss the positive and negative effects of FSS and derive policy implications. For this purpose, we conducted a systematic literature review. Although FSS can be applied at the micro (i.e., individual or household) level [78], in this literature review, we consider only empirical and theoretical studies that focus on FSS as an outcome at the macro (i.e., country or regions within a country) level.

To the best of our knowledge, this is the first study to develop a framework based on a systematic review of the factors affecting the production and consumption components of FSS at the country level. Accordingly, this study helps policymakers seeking to strengthen FSS by providing a systematic overview of the factors affecting FSS, their direction of effect, and which factors can be changed by whom and how. Furthermore, this study contributes to the historical debate on FSS versus trade liberalization by discussing the potential positive and negative effects of FSS as a policy objective [113].

The paper is organized as follows. In Section 2, we describe the methods used. In Section 3, we present the results and discuss them in Section 4. We conclude the paper and provide policy implications in Section 5.

2. Methods

2.1. Systematic literature review

In September 2024, we conducted a systematic literature review of studies focusing on the factors affecting FSS at the macro level (i.e., country or regions within a country). To select relevant studies, we followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [93]. Because the discussion on FSS has a historical dimension, we did not impose any restrictions on the year of publication. We also imposed no restrictions on the type of scientific study (i.e., peer-reviewed study, working paper, book chapter, study published in conference proceedings, research reports). Our goal was to keep the search strategy as broad as possible, so we did not impose restrictions on quantitative or qualitative methods. The focus of our literature search was on the factors affecting FSS or the determinants of FSS. Accordingly, FSS should be the main outcome or one of many outcomes in the included studies. The Web of Science and Scopus databases were used for the literature search. The search strings used and the resulting number of publications, grouped by the Web of Science and Scopus databases, are presented in Table 1.

Table 1
The search strings used and the resulting number of publications separated by the Web of Science and Scopus databases.

Search strings	Number of publications in Web of Science	Number of publications in Scopus
food AND self-sufficiency AND determinants	29	66
food AND self-sufficiency AND influencing AND factors	46	51
food AND self-sufficiency AND explaining AND factors	5	3
food AND self-sufficiency AND global	236	462
food AND self-sufficiency AND comparative	31	102
food AND self-sufficiency AND trends	126	297
Total	473	981

Fig. 1 outlines the search process used to select relevant studies focusing on factors affecting FSS based on the PRIMSA reporting guidelines.

In total, we identified 1454 scientific studies by searching the two databases. In the first step, we screened 703 studies after removing duplicates, studies we could not access, and studies that were not available as a downloadable PDF. In the second step, abstracts and titles were scanned. A study was included if (i) it was in English,[1] (ii) it focused on FSS, (iii) the geographical unit was a country, a group of countries (including the global view), a region within a country, or multiple regions within a country, and (iv) it was a primary source (i.e., not a literature review as ours). In the third step, the criteria were applied to evaluate 303 full texts. Finally, 92 studies (90 peer-reviewed studies, 1 research report, and 1 working paper) were selected based on the defined criteria. The references of the selected studies can be found in Appendix A.

2.2. Analyses of selected studies

2.2.1. Analysis of study characteristics

The following four study characteristics were analyzed descriptively (see Table 2 for an overview). The first is the measurement of FSS. FSS is usually measured as a ratio, with domestic production as the numerator and domestic consumption as the denominator. In some studies, the consumption component of FSS has been further specified. For example, according to the FAO [57] definition of the FSS ratio, the availability of food for domestic consumption (i.e., the denominator) is calculated as domestic production plus imports minus exports. Deng et al. [44] classified domestic grain consumption by use (i.e., human, industrial, feed, seed, and losses). The second is the methodological approach of the study. For example, studies using models predicting the future effects of tariff cuts on agricultural trade and domestic production were classified as "quantitative ex-ante," while studies relying on a regression analysis based on historical data were classified as "quantitative ex-post." A third

[1] In line with Pieper and Puljak (2021) [153] we defined "English-speaking study" as an eligibility criterion. We did not consider non-English studies eligible for two reasons: First, translating from a non-English language to English is imprecise due to a lack of foreign language proficiency. Second, selecting English-speaking studies allows an international audience to understand the content of the selected studies. Although not considering non-English studies may be associated with overlooking relevant factors influencing FSS (Jackson & Kuriyama, 2019; Dobrescu et al., 2021), we do not believe this is the case here. The selected studies reveal a broad set of relevant factors. In total, we identified n = 20 non-English studies in the literature research, but $n = 16$ were excluded after assessing titles and abstracts. Thus, $n = 4$ non-English-speaking studies remained for the eligibility assessment.

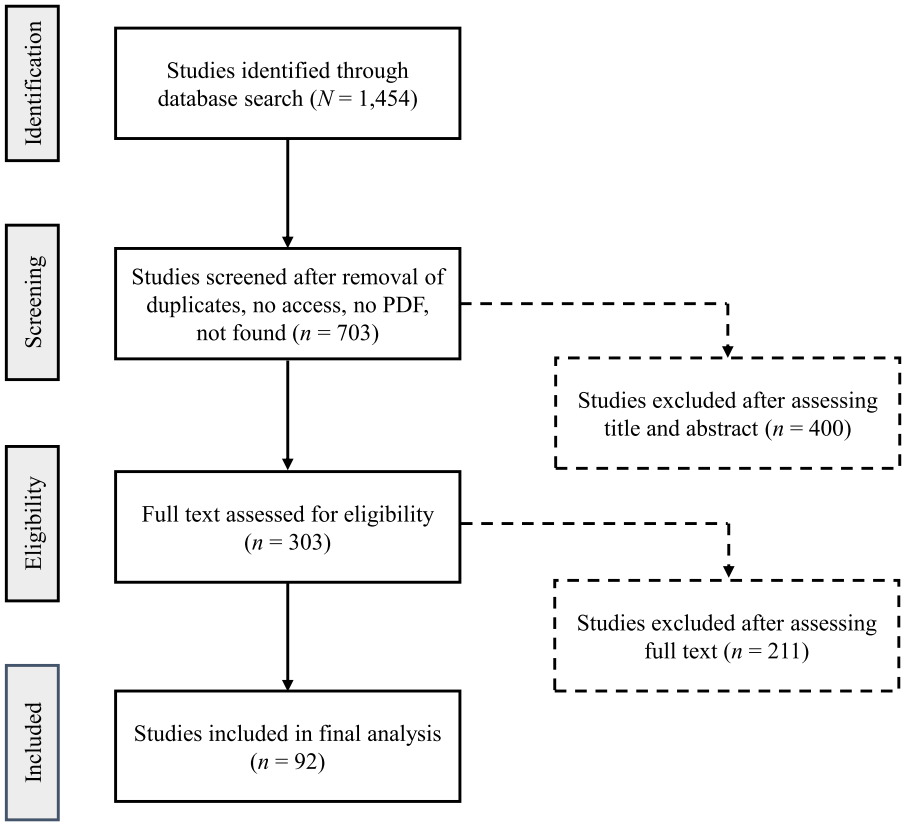


Fig. 1. The search process used to identify studies focusing on factors affecting FSS based on the PRISMA reporting guidelines.

Table 2
Overview of descriptively analyzed study characteristics.

(1) Measurement FSS
1 = Domestic production/domestic consumption
2 = Other definition of FSS
3 = No definition of FSS
(2) Methodological approach
1 = Quantitative ex-ante
2 = Quantitative ex-post
3 = Quantitative ex-post and ex-ante
4 = Quantitative no time dimension
5 = Qualitative narrative
6 = Qualitative narrative + descriptive statistics
7 = Qualitative interviews
(3) Product
1 = Multiple grains (e.g., rice, wheat, maize, soy)
2 = Single grains
3 = Animal-based (meat and dairy products)
4 = Plant-based (fruits, vegetables, oils, grains)
5 = Animal- and plant-based
6 = No specification
(4) Geographical unit
1 = Single developing country
2 = Group of developing countries
3 = Single industrialized country
4 = Group of industrialized countries
5 = World
6 = Other

feature is the food products used for the calculation of FSS. For example, a group of food products consisting of fruits and vegetables (incl. roots and tubers), vegetable oils and fats, and grains were categorized as "plant-based food products". The fourth is the geographical unit of a study. For example, the geographical unit of a study could be a single developing country,[2] such as Vietnam and Thailand, or a group of developing countries, such as all countries on the African continent. To analyze the four study characteristics descriptively, we created an Excel file with four variables (i.e., FSS measurement, methodological approach, products, and geographical unit). Each of the four variables was assigned a specific value ranging from 1 to 4. For example, the variable "FSS measurement" had the values "1 = Domestic production divided by domestic consumption," "2 = Other definition of FSS," and "3 = No definition of FSS." Finally, we counted the absolute frequency of the selected studies per year for the period 1982–2024.

2.2.2. Grouping individual FSS factors and determining of direction of effects

Inductive coding was used to group individual factors affecting FSS into categories. For this purpose, we followed the five-step coding process suggested by Creswell [41]. In the first step, we created a variable "factors" in the Excel file. In the second step, we screened the texts with a focus on factors affecting FSS and wrote the types of factors into the variable "factors" separated by commas. Where possible, we divided the factors into production factors and consumption factors. In the third step, we created a first draft of FSS categories based on the types of factors. This means that for each category, we created a variable (i.e., a column) that counts the frequency. If a factor was related to a category, we inserted a 1; otherwise, we inserted a 0. Creating dummy variables allowed us to calculate the absolute frequency (i.e., relevance) of a category. In the fourth step, because some factors could potentially be assigned to more than one category, we had to avoid overlapping coding. This implies that the factors were only assigned to one category. In the final step, we refined the categories by linking or combining them. We also created a variable (i.e., a column) that counted the frequency for each factor. If a factor was related to a study, we inserted a 1; otherwise, we assigned a 0, so that we could calculate the absolute frequency (i.e., the relevance) of a factor across all studies. Furthermore, we derived the effect direction (i.e., positive, negative, or mixed) of the FSS factors. We also used information on the absolute frequency of a factor combined with information on geographical units (see Table 2). This allowed us to demonstrate geographical heterogeneity by showing the frequency distribution of factors across geographical units.

The diversity of the methodological approaches and FSS measurements did not always allow for a clear identification of the direction, magnitude, and statistical significance of the effect. The diversity of methodological approaches and FSS measurements did not allow for clear identification of the magnitude, and statistical significance of the effect. However, we only found five studies that empirically quantified the effect of the factors using regression analysis [27,28,51,57,99], which is insufficient for a meta-regression analysis. Therefore, we considered a broad set of methodological approaches in our systematic literature review to obtain a sufficient number of studies. Our study focused on the types of influencing factors and their effect direction. Furthermore, it was not always possible to separate the effects of domestic production from domestic consumption. For example, the quantitative ex-ante models used by Xu et al. [143] and ten Berge et al. [148] considered production inputs or macroeconomic factors to predict future FSS. However, the effect direction of the factors used cannot be identified. Furthermore, 40 studies did not define how they measured FSS (see Table B4 in Appendix B). Accordingly, we did not distinguish between domestic production and consumption with regard to the direction of the effect. Nevertheless, in the interpretation of the results, we distinguished between domestic production and domestic consumption where possible.

2.2.3. An approach to classifying actors and actions influencing food self-sufficiency

The factors affecting FSS (i.e., domestic production and consumption) can be influenced by multiple actors and actions. To classify actors and actions, we adapted the multi-actor constellation approach developed by Berrang-Ford et al. [21] .[3] In our context, we identified producers (i.e., farmers), consumers (i.e., individuals or households), and policymakers as relevant actors that possibly influence FSS. The potential types of actions are i) behavioral/cultural, (ii) technical/-infrastructural, (iii) ecosystem-based, and (iv) institutional [21]. In our study, a behavioral or cultural action reflects a change in consumption behavior toward a more plant-based diet. The adoption of new agricultural production technologies by farmers represents a "technical/-infrastructural" action. Ecosystem-based mitigation is part of nature-based solutions, which represent actions to manage or restore natural or modified ecosystems to adapt to, for example, climate change, water scarcity, or natural disasters [58]. Institutions such as laws, regulations, obligations, and prohibitions guide human behavior. Accordingly, policymakers are responsible for the "institutional" action. Each type of action was coded as a binary decision (i.e., 1 = can be influenced; 0 = cannot be influenced).

3. Results

3.1. Study characteristics

Fig. 2 shows bubble matrices representing the relationship between a study characteristic on the x-axis and a study characteristic on the y-axis. Bubble sizes reflect the absolute frequency (i.e., number) of the studies, with the total number of studies in each panel adding up to 92. The panels present the relationship between the (a) geographical unit and product, (b) FSS measurement and product, (c) methodological approach and product, (d) methodological approach and geographical unit, and (e) methodological approach and FSS measurement. The underlying descriptive statistics for each of the four study characteristics can be found in Table B1 (geographical unit), Table B2 (product), Table B3 (methodological approach), and Table B4 (FSS measurement) in Appendix B.

The selected studies had a strong focus on single developing countries (n = 61; see Table B1 in Appendix B). Many of the developing countries depend on imports of grains such as rice, wheat, corn, and soybeans and are therefore more vulnerable to trade shocks [60]. These studies mainly investigated multiple grains (n = 17), and single grains (n = 13) (Fig. 2a). The FSS ratio (i.e., domestic production divided by domestic consumption) was frequently used to measure the FSS of multiple grains (n = 15) and animal- and plant-based products (n = 14). (Fig. 2b). Studies that used quantitative ex-ante and ex-post models mainly focused on multiple grains (n = 9 and n = 12) and a combination of animal- and plant-based food products (n = 9 and n = 7) (Fig. 2c). The geographical units of the studies that used ex-ante and ex-post models were single developing countries (n = 19) and groups of developing countries (n = 17) (Fig. 2d). In total, 40 studies did not define the measurement of FSS. In particular, studies combining narrative evidence and descriptive statistics and studies using quantitative ex-ante models

[2] The country classifications "developing country" and "industrialized / developed country" are based on UN [130]. For simplicity, we use the term "developing country". This term also includes transition countries and least developed countries.

[3] Berrang-Ford et al. [21] conducted a literature review to identify actors and types of actions needed for climate change adaptation. For the sake of simplicity, we do not differentiate actors with respect to the geographic levels of local, national, and international.

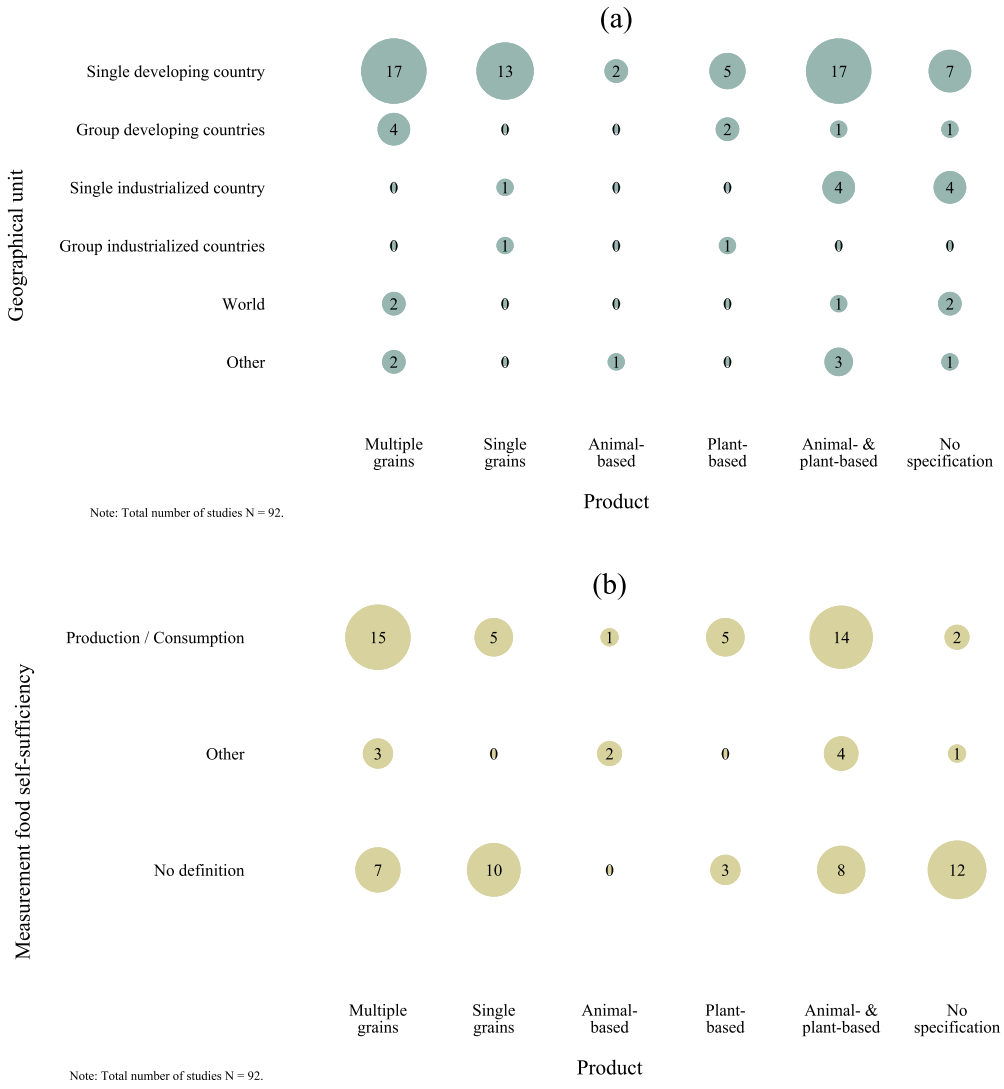


Fig. 2. Bubble matrices depicting the relationship between (a) geographical unit and product, (b) FSS measurement and product, (c) methodological approach and product, (d) methodological approach and geographical unit, and (e) methodological approach and FSS measurement. Bubbles sizes reflect the absolute frequency (i.e., number) of the studies. The total number of studies always adds up to $N = 92$.

did not define how they measured FSS ($n = 14$ and $n = 12$) (Fig. 2e).

Fig. 3 shows the absolute frequency of the selected studies per year for the period 1982–2024. The blue dashed line refers to the 2007–2008 food price crisis, the red dashed line refers to the outbreak of the COVID-19 pandemic in 2020, and the green dashed line refers to the start of the war in Ukraine in 2022.

Between 1982 and 2007–2008, the number of scientific studies focusing on factors affecting FSS ranged from 0 to 2. Surprisingly, the 2007–2008 food price crisis did not lead to an immediate increase in the number of scientific studies. However, the number of scientific studies rose steadily starting in 2012, with a significant increase observed since the COVID-19 pandemic and the war in Ukraine. Additionally, research on the effects of climate change and extreme weather events on agricultural production has gained momentum since 2010 [90]. Besides shocks such as the COVID-19 pandemic and the war in Ukraine, the increased focus on climate change and extreme weather events may also explain the steady rise in scientific studies since 2012.

3.2. *A framework of factors affecting national food self-sufficiency and their effect direction*

Fig. 4 shows the framework with categories, the factors affecting national FSS, and the direction of the effect (i.e., positive, negative, or mixed) of each factor. The frequency of categories and the frequency of factors affecting FSS can be found in Table B5 in Appendix B.

We define external events as events that are largely beyond the control of individual nations. They include long-term environmental trends, such as climate change and extreme weather events, wars, harmful organisms, and nuclear disasters. By contrast, the remaining categories (i.e., agricultural inputs, alternative agricultural systems, macroeconomic factors, dietary habits, food waste and losses, urbanization, agricultural policy, and trade policy) are largely within the control of individual nations. A descriptive analysis revealed a strong focus of selected studies on agricultural inputs ($n = 49$), followed by macroeconomic factors ($n = 33$), external events ($n = 29$), and dietary habits ($n = 28$). By comparison, the categories of agricultural policy ($n = 14$), trade policy ($n = 13$), urbanization ($n = 11$), alternative agricultural systems ($n = 7$), and food waste and losses ($n = 5$) were underrepresented.

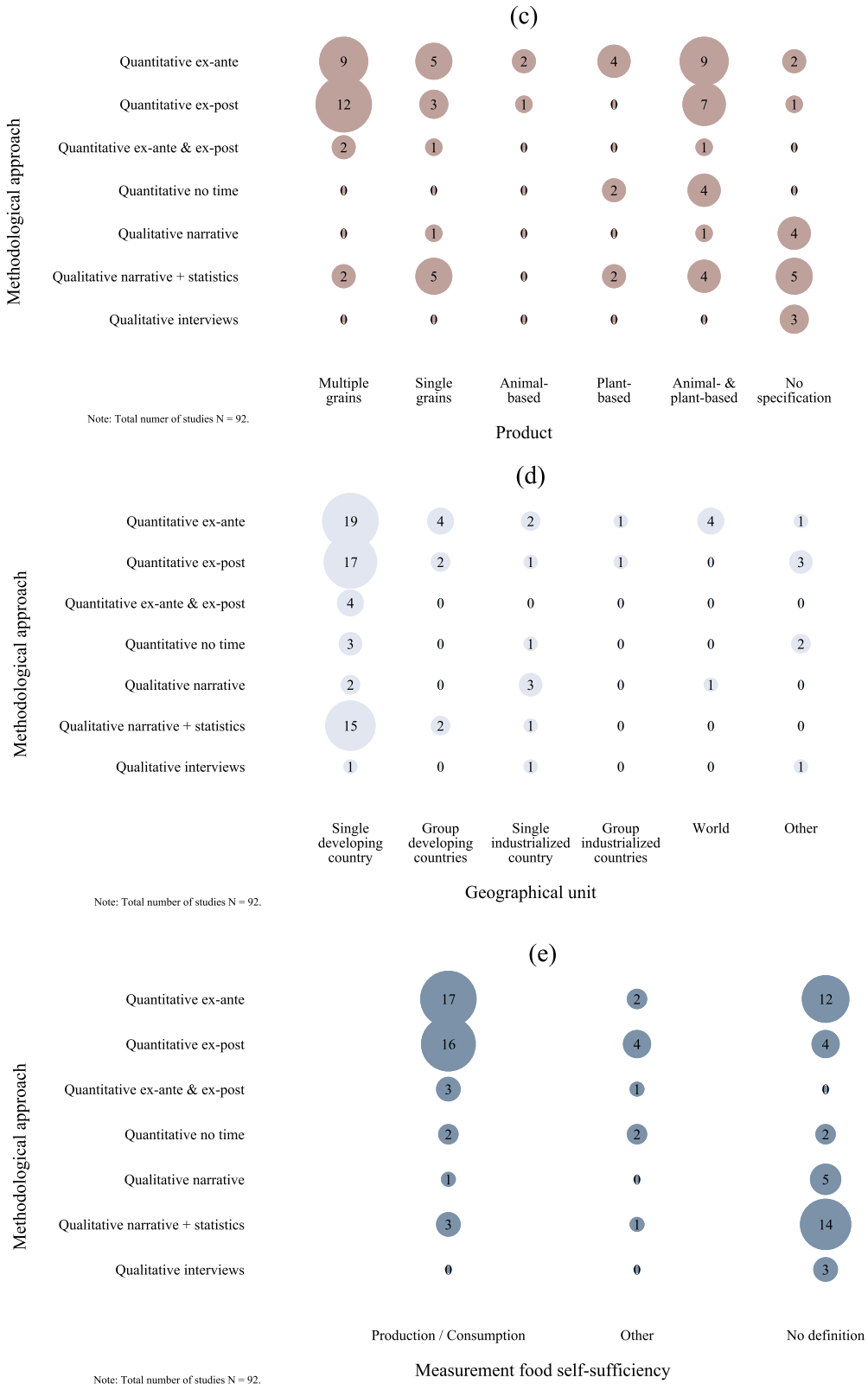


Fig. 2. (*continued*).

Climate change (i.e., the long-term variation in global surface temperature) and related extreme weather events were the most relevant external events influencing FSS ($n = 23$ and $n = 7$). Climate change was expected to reduce FSS by having a negative impact on agricultural production (e.g., [19,81,138]). The same was true for extreme weather events, such as hails, floods, storms, and droughts (e.g., [50,112,118]). Precipitation and solar radiation positively affected FSS by creating favorable natural conditions for agricultural production (e.g., [88,122,135]). Wars [97], nuclear disasters [26], diseases, and harmful organisms [85] have all negatively affected FSS by limiting agricultural

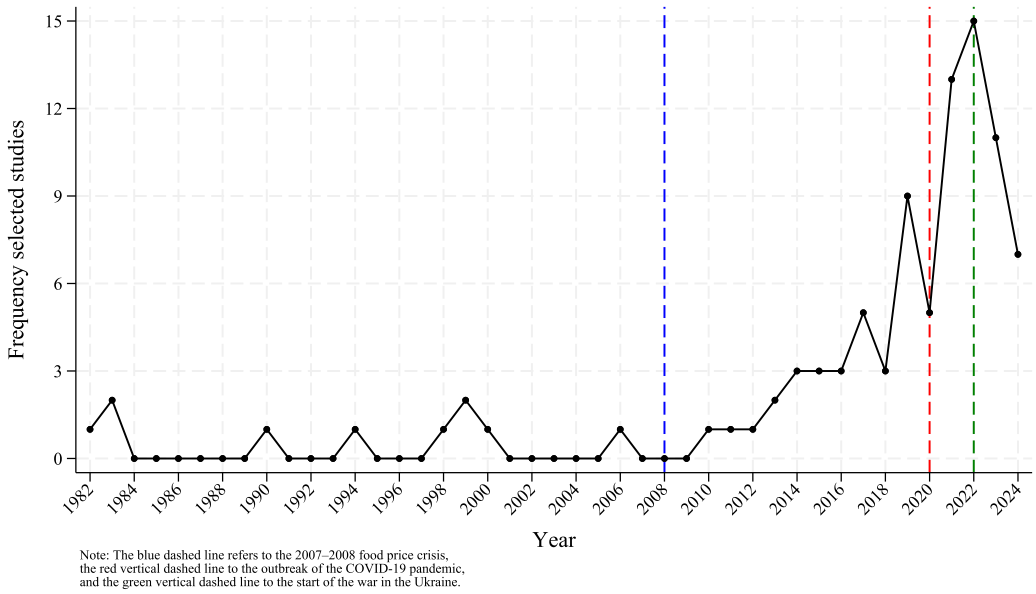


Fig. 3. The absolute frequency of the selected studies per year for the period 1982–2024.

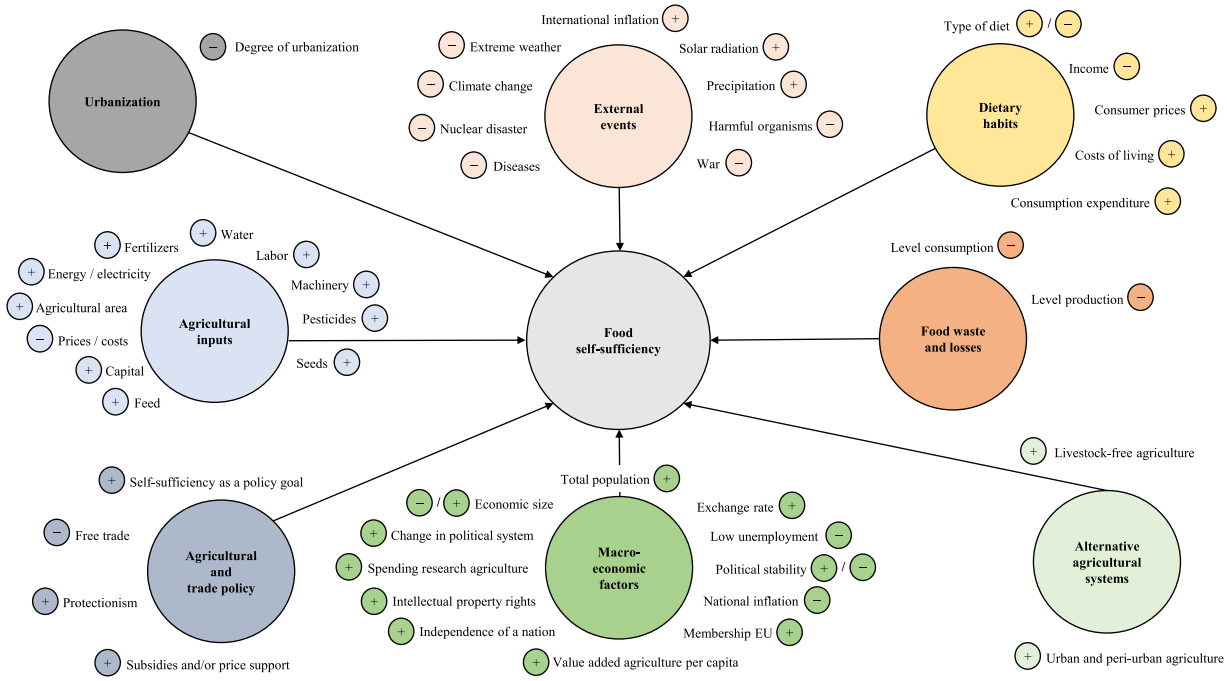


Fig. 4. The framework with the categories, factors affecting national FSS, and direction of effect of each factor. '+' denotes a positive impact on FSS; '−' denotes a negative impact on FSS; '+/−' denotes a mixed impact on FSS.

production. Interestingly, the results by Erokhin [51] suggested a positive effect of international inflation (i.e., rising prices in the world market) on FSS.

Due to its limited availability, agricultural area (e.g., arable land or pastures) was the most relevant production mean influencing FSS (n = 37). This factor included the absolute size of the area (e.g., [35,80]), the area available per capita [84], the irrigated area (e.g., [42,68]), the share of agricultural area in a country's total area [32], and the water storage capacity [19]. In principle, intensifying agricultural production (i.e., increasing yields) by expanding the agricultural area or using more inputs such as fertilizers (e.g., [27,43,75]), water (e.g., [91,96,110]), labor (e.g., [7,99,139]) and machinery (e.g., [30,134,143]) had a positive effect on FSS. A shortage of inputs, such as abandoned farmland due to urbanization in turn led to a decrease in agricultural production (e.g., [47,81,86]. Rising prices or costs of inputs led to declining agricultural production [98,109].

The total population living in a country, population growth, population density, and economic size, or growth in the economic size of a country (i.e., gross domestic product/gross national income, gross domestic product/gross national income per capita, and agricultural gross domestic product) were the most relevant macroeconomic factors (n = 27 and n = 18). In particular, population growth in developing countries was expected to negatively affect FSS by increasing food demand (e.g., [7,14,127]). In this context, a low unemployment rate in Japan was associated with a low incentive to work in agriculture, leading to threats to agricultural production [133]. Luan et al. [87], for example, used

gross domestic product per capita as a proxy for purchasing power and found a negative correlation with FSS. By contrast, the regression results from Brankov et al. [28] revealed mixed effects of gross domestic product on FSS at the product group level (e.g., FSS for eggs or cereals). Mixed effects were also found for the political stability of a country [28,80,97]. The number of intellectual property rights, which represent a country's ability to innovate to increase the efficiency of agricultural production [36], and high spending on agricultural research [75] positively affected FSS by increasing agricultural production. Whereas the exchange rate was positively associated with FSS, national inflation was negatively associated with FSS [51]. A change in the political system (i.e., from communism to capitalism) [16] and independence [122] had positive effects on FSS, while EU membership had mixed effects on FSS [28].

The type of diet (i.e., level of consumption, total demand, demand per capita, growth in demand, and dietary change) was the most relevant factor related to dietary habits ($n = 25$). While a change in dietary habits from an animal-based diet to a plant-based diet increased FSS because more food was available for human consumption, the opposite was true for a change in dietary habits from a plant-based diet to an animal-based diet (e.g., [17,20,44,66]). High income (per capita) was associated with an increase in food demand (e.g., [77,82]), while high consumer prices (e.g., [44,106]), consumption expenditures for non-food products (e.g., [75,149]), and the costs of living limited food demand [143], thereby increasing FSS.

Especially in developing countries, such as China or Indonesia, FSS was defined as a policy goal ($n = 10$) (e.g., [11,50]). For example, with the green revolution in the early 1960s, governments in many developing countries provided subsidies and/or price support to farmers to enable them to invest in modern production technologies (e.g., high-yield seeds, machinery, chemical pesticides, and fertilizers) (e.g., [102,105]). The intensification of agricultural production led to an increase in agricultural yields and an increase in FSS. Trade policy[4] was characterized by two opposing poles: free trade and protectionism. While the reduction of tariff and non-tariff measures put pressure on domestic agricultural production (e.g., [10,72]), the increase or maintenance of high levels of tariff and non-tariff measures was associated with the protection of domestic agricultural production (e.g., [8,45]). Accordingly, free trade was considered to reduce FSS, while protectionism was considered to increase FSS.

Alternative agricultural production systems in urban and peri-urban areas were associated with increases in agricultural production, and thus increases in FSS. Alternative agricultural production systems comprise, for example, rooftop greenhouses [33], indoor and vertical farming [1], and aquaponics [12]. The conversion from plant-based to animal-based proteins in livestock farming was associated with losses. Livestock-free agriculture avoided these losses and allowed farmers to use agricultural land to produce food for human consumption instead of animal feed. Accordingly, a larger amount of agricultural production was available for human consumption, which increased FSS [17].

Food waste and losses occurred either at the production stage [5,20] or at the consumption stage [14,85,120]. Whereas food waste and losses at the production stage reduced the supply of agricultural products, food waste and losses at the consumption stage created additional demand. Thus, food waste and losses had a negative impact on FSS.

3.3. Geographical heterogeneity in factors affecting food self-sufficiency

Table 3 shows the frequency distribution of factors affecting FSS across geographical units: single developing country, group of developing countries, single industrialized country, group of industrialized countries, world, and other.

Due to the strong focus of selected studies on developing countries ($n = 61$ single developing country; $n = 8$ group of developing countries), we found that most of the factors are more relevant in those countries. This is most evident in the categories agricultural inputs, macroeconomic factors, and dietary habits. Factors with a total frequency greater than one, such as extreme weather events ($n = 7$), energy and electricity ($n = 5$), FSS as a policy goal ($n = 10$), subsidies and/or price support ($n = 4$), and food waste at the consumption level ($n = 3$), were exclusively relevant in developing countries. Only the factor climate change was distributed relatively equally across geographical units, highlighting its global relevance. Conversely, technological and cultural developments in alternative agricultural systems were more prevalent in industrialized countries ($n = 3$, urban and peri-urban agriculture, and $n = 1$, livestock-free agriculture) than in developing countries ($n = 2$, urban and peri-urban agriculture) and other geographical units ($n = 1$, urban and peri-urban agriculture).

3.4. Actors and actions influencing food self-sufficiency

Table 4 shows the actors (i.e., consumers, producers, and policymakers) and actions (i.e., cultural/behavioral, technological/infrastructural, ecosystem-based, and institutional) that can influence the factors that affect FSS. Factors that can be influenced by an actor's action are marked with a check symbol '✓', and those that cannot are marked with a cross symbol '×'.

In countries where FSS is a policy goal, policymakers have a responsibility to support factors that have a positive impact on FSS and to eliminate or reduce factors that have a negative impact on FSS. Accordingly, except for natural conditions (i.e., solar radiation and precipitation) and external shocks (i.e., wars, diseases, harmful organisms, nuclear disasters, and international inflation), policymakers at the national level are responsible for the institutional framework (i.e., legislation). This applies to effective national institutions for climate change mitigation and adaptation [48], the stability of the macroeconomic environment [76], reliable conditions for agricultural producers [49] and trade partners [126], for limiting the negative impacts of urbanization [83], incentivizing environmentally friendly diets [73], and the mitigation of food waste and losses [31].

Consumers can contribute to climate change mitigation and sustainable resource use through behavioral change by adopting more sustainable diets. For example, a plant-based diet is associated with lower greenhouse gas emissions [39] and reduced use of natural resources, such as land or water [103] and is therefore considered as more environmentally sustainable. The use of environmentally friendly household appliances, such as dishwashers or refrigerators/freezers, that have a longer lifespan, are made from recycled materials, or use less energy also helps reduce energy and resource consumption [13]. As a result, the sustainable use of energy and materials was associated with a reduction in greenhouse gas emissions, which had a positive impact on the climate and, thus, on FSS. Reducing avoidable food waste at the consumer level can promote energy, economic and environmental sustainability [62]. This can be achieved through behavioral changes, such as shopping from a list or creating a 3–4-day meal plan [24]. Technologies such as smartphone apps for food planning, shopping, storage, and cooking can complement behavioral changes to reduce food waste [22].

Producers can also contribute to the mitigation of climate change and thus help limit the negative effects of climate change on FSS. Behavioral change and technology adoption are also complementary in achieving a more sustainable agricultural production. The extensification of agricultural production by reducing livestock production is considered an effective option for mitigating greenhouse gas emissions [18]. In this context, the findings of Slater et al. [119] show that shifting agricultural production from fresh vegetative products to more storable products such as cereals, oils, fats, legumes, seeds, and nuts can increase food self-sufficiency. The application of precision agriculture

[4] Ex-ante trade models used bilateral trade flows (i.e., imports and exports), data on tariffs and non-tariff barriers to trade, and data on supply and demand elasticities, which were not considered in our framework.

Table 3
Frequency distribution of factors affecting FSS across geographical units: single developing country, group of developing countries, single industrialized country, group of industrialized countries, world, and other.

Category	Factors	Single developing country	Group of developing countries	Single industrialized country	Group of industrialized countries	World	Other	Total frequency
External events	Climate change	8	4	2	0	4	5	23
	Extreme weather events	6	1	0	0	0	0	7
	Precipitation	2	1	0	0	0	1	4
	Solar radiation	1	0	0	0	0	0	1
	War	1	0	0	0	0	0	1
	Diseases	1	0	0	0	0	0	1
	Harmful organisms	1	0	0	0	0	0	1
	Nuclear disasters	0	0	0	0	0	1	1
	International inflation	1	0	0	0	0	0	1
Agricultural inputs	Agricultural area	22	7	2	1	1	4	37
	Fertilizers	15	2	1	0	0	2	20
	Water	9	5	0	0	2	2	18
	Labor	8	0	2	0	0	0	10
	Machinery/Technology	7	0	1	0	0	0	8
	Pesticides	6	0	1	0	0	0	7
	Seeds	6	0	1	0	0	0	7
	Feed	3	0	2	0	0	0	5
	Energy and electricity	5	0	0	0	0	0	5
	Prices/costs	2	0	1	0	0	0	3
	Capital	1	0	1	0	0	0	2
Macroeconomic factors	Population	17	3	1	1	1	4	27
	Economic size	10	2	1	0	0	5	18
	Political stability	1	0	0	0	0	2	3
	Low unemployment rate	0	0	1	0	0	0	1
	Intellectual property rights	1	0	0	0	0	0	1
	Spending research in agriculture	1	0	0	0	0	0	1
	Exchange rate	1	0	0	0	0	0	1
	National inflation	1	0	0	0	0	0	1
	Value added agriculture	0	0	0	0	0	1	1
	Membership in EU	0	0	0	0	0	1	1
	Independence	0	1	0	0	0	0	1
	Change in political system	0	1	0	0	0	0	1
Dietary habits	Type of diet	12	3	3	2	2	3	25
	Income	5	1	0	1	0	1	8
	Consumer prices	3	1	1	0	0	0	5
	Consumption expenditure	2	0	1	0	0	0	3
	Costs of living	1	0	0	0	0	0	1
Agricultural policy	Food self-sufficiency as a policy goal	9	1	0	0	0	0	10
	Subsidies and/or price support	4	0	0	0	0	0	4
Trade policy	Free trade	5	1	1	0	1	1	9
	Protectionism	5	0	0	0	1	0	6
Urbanization	Degree of urbanization	9	0	0	0	0	2	11
Alternative agricultural systems	Urban and peri-urban agriculture	2	0	3	0	0	1	6
	Livestock-free agriculture	0	0	1	0	0	0	1
Food waste and losses	Level of consumption	3	0	0	0	0	0	3
	Level of production	1	0	1	0	0	0	2

technologies can, for example, optimize fertilizer application and thus reduce greenhouse gas emissions [65]. The implementation of ecosystem-based adaptation solutions, such as mulching or cover crops, helps improve water infiltration rates and thus adapts to climate change-induced droughts [58]. The counterpart of extensification is the intensification of agricultural production, which is also driven by a combination of behavioral changes and the use of new technologies. A prime example is the green revolution, which was a critical turning point for traditional agricultural methods [107]. The introduction of high-yielding crop varieties, fertilizers, irrigation, and pesticides led to high yields [101]. If urban agriculture is considered an entrepreneurial activity, the expansion of agricultural production through smart technologies is also a combination of cultural change and the adoption of new technologies [123]. Food waste at the farm level could be reduced, thereby increasing the available supply and positively impacting FSS. For example, potatoes that are not consumed for aesthetic reasons are not sorted out by farmers but are later channeled by wholesalers [140]. Research shows that suboptimal potatoes are accepted by consumers who have been made aware of the amount of food wasted for aesthetic reasons [6]. In addition, crop losses at the farm level can be valorized, for example, by producing biofuels or methane as a substitute for liquefied natural gas [97].

Table 4
The actors and actions influencing the factors affecting FSS.

Categories	Individual factors	Policymakers	Consumers		Producers		
		Institutional	Cultural/ behavioral	Technological/ infrastructural	Cultural/ behavioral	Technological/ infrastructural	Ecosystem-based
External events	Climate change	✓	✓	✓	✓	✓	✓
	Extreme weather events	✓	✓	✓	✓	✓	✓
	Precipitation	×	×	×	×	×	×
	Solar irradiation	×	×	×	×	×	×
	War	×	×	×	×	×	×
	Diseases	×	×	×	×	×	×
	Harmful organisms	×	×	×	×	×	×
	Nuclear disasters	×	×	×	×	×	×
	International inflation	×	×	×	×	×	×
Agricultural inputs	Agricultural area	✓	×	×	✓	✓	×
	Fertilizers	✓	×	×	✓	✓	×
	Water	✓	×	×	✓	✓	×
	Labor	✓	×	×	✓	✓	×
	Machinery/Technology	✓	×	×	✓	✓	×
	Pesticides	✓	×	×	✓	✓	×
	Seeds	✓	×	×	✓	✓	×
	Feed	✓	×	×	✓	✓	×
	Energy and electricity	✓	×	×	✓	✓	×
	Prices/costs	✓	×	×	✓	✓	×
	Capital	✓	×	×	✓	✓	×
Macroeconomic factors	Population	✓	×	×	×	×	×
	Economic size	✓	×	×	×	×	×
	Political stability	✓	×	×	×	×	×
	Low unemployment rate	✓	×	×	×	×	×
	Intellectual property rights	✓	×	×	×	×	×
	Spending research in agriculture	✓	×	×	×	×	×
	Exchange rate	✓	×	×	×	×	×
	National inflation	✓	×	×	×	×	×
	Value added agriculture	✓	×	×	×	×	×
	Membership in EU	✓	×	×	×	×	×
	Independence	✓	×	×	×	×	×
	Change in political system	✓	×	×	×	×	×
Dietary habits	Type of diet	✓	✓	×	×	×	×
	Income	✓	×	×	×	×	×
	Consumer prices	✓	×	×	×	×	×
	Consumption expenditure	✓	✓	×	×	×	×
	Costs of living	✓	×	×	×	×	×
Agricultural policy	Policy goal food self-sufficiency	✓	×	×	×	×	×
	Subsidies and/or price support	✓	×	×	×	×	×
Trade policy	Free trade	✓	×	×	×	×	×
	Protectionism	✓	×	×	×	×	×
Urbanization	Degree of urbanization	✓	×	×	×	×	×
Alternative systems	Urban and peri-urban agriculture	✓	×	×	✓	✓	×
	Livestock-free agriculture	✓	×	×	✓	✓	×
Food waste and losses	Level of consumption	✓	✓	✓	×	×	×
	Level of production	✓	×	×	✓	✓	×

Note: Factors that can be influenced by an actor's action are marked with a check symbol '✓', and those that cannot are marked with a cross symbol '×'.

3.5. Actors and actions promoting sustainable development and food self-sufficiency

In this subsection we synthesize the findings obtained through the multi-actor constellation approach regarding actors and actions that promote sustainable development and FSS. We identified four types of actions that can promote both environmental sustainability and FSS (see Table 5).

We identified policymakers in being responsible for the development and implementation of agricultural and trade policies that focus on sustainability and FSS [55,145]. The EU's common agricultural policy, for example, sets ambitious goals for greening agricultural production by reducing negative external effects such as greenhouse gas emissions from livestock farming, while fostering positive externalities such as biodiversity conservation [53]. Moreover, the EU considers sustainable development as a key principle in modern trade agreements [54]. The integration of sustainability standards into free trade agreements can mitigate negative environmental externalities caused by trade liberalization [70,128]. Policies that adjust food prices, for example, can promote more sustainable consumption patterns by increasing the consumption of fresh foods and reducing food waste [69].

While the agricultural policy sets the framework for a transition to more sustainable configurations of the food system, we found that producers can adopt sustainable farming practices that increase production levels, and thus FSS. Promising approaches to promoting environmental sustainability include alternative agricultural systems such as livestock-free agriculture and urban and peri-urban agriculture in the form of rooftop greenhouses or aquaponics [67,115,116]. Sustainable

Table 5
Actors and actions promoting sustainable development and food self-sufficiency.

Actions	Policymakers	Consumers	Producers
Policies integrating sustainability as a goal	✓	×	×
- Greening agriculture			
- Environmental trade standards			
Sustainable production	✓	×	✓
- Livestock-free agriculture			
- Urban and peri-urban agriculture			
- Sustainable intensification			
- Smart farming technologies			
Sustainable consumption	✓	✓	×
- Plant-based diet			
Reducing food waste and losses	✓	✓	✓
- Waste management			
- Smart technologies and sharing platforms			

Note: Actions that can be influenced by an actor and that promote sustainable development and FSS are marked with a check symbol (✓), and those that cannot be influenced are marked with a cross symbol (×).

intensification in traditional agriculture aims to raise productivity while increasing resource use efficiency and reducing the negative environmental impacts of agriculture [142]. In this context, smart farming technologies reduce inefficiencies, enhance resource productivity, and lower management costs. These technologies positively impact production levels and contribute to FSS [34,111]. Waste management practices at the farm level, such as donating or selling food at discounted rates, can reduce food waste [74].

Furthermore, our findings revealed that consumers can play a significant part in making the food system more sustainable. In this context, policy interventions are needed to reduce, change and improve consumption [94]. Clear environmental benefits were identified in adopting sustainable diets such as plant-based ones [114]. Moreover, reducing avoidable food waste was found to enhance FSS while alleviating pressure on natural resources [64]. According to Agya [3], smart technologies such as AI-powered management systems and smart refrigerators, as well as food-sharing platforms, can help avoid food waste.

4. Discussion

To the best of our knowledge, this is the first study to systematically identify factors affecting FSS at the country level using a systematic literature review. In this section, we focus on discussing the limitations of three factors that seemed easily influenced by producers and/or consumers for the consequent positive impact on FSS. First, the intensification of agricultural production by using more agricultural inputs, such as machinery, fertilizers, and pesticides. Second, a shift in consumption patterns toward more sustainable diets. Third, the reduction of avoidable food waste. Additionally, we aim to discuss the results of the analysis of geographical heterogeneity.

Agricultural policies that promoted the intensification of agricultural production during the green revolution have enabled developing countries in Asia and Latin America to achieve FSS [15]. However, with the modernization and professionalization of agricultural production, farmers have become more dependent upon privately regulated markets, retailers, research, and policy measures [71]. Furthermore, the intensification of agricultural production has led to severe environmental impacts, such as soil degradation and runoff from chemical fertilizers and pesticides [104]. Although intensification of agricultural production has been associated with increases in yields in the short and medium term, soil degradation leads to adverse trends in yields in the long term that threaten FSS [125]. This calls for more environmentally and socio-economically sustainable agricultural practices. In this context, sustainable intensification practices, such as increasing crop diversity, adopting intercropping systems or adding fertility crops or organic matter, have shown positive effects on the yield of staple crops [89,124]. Accordingly, the concept of the sustainable intensification of agricultural production may hold promise for securing future yields and, thus, FSS [20]. Building on this, the EU's "Farm to Fork Strategy" sets ambitious goals to accelerate the transition to a more sustainable food system. These goals include reducing environmental impacts, mitigating and adapting to climate change, conserving biodiversity, promoting healthy diets, and ensuring food security and fair trade [150]. While these goals traditionally target rural agricultural systems, they are increasingly relevant in urban contexts as well. Alternative agricultural systems, such as rooftop greenhouses and aquaponic systems, enable sustainable food production by enhancing FSS of urban spaces, promoting biodiversity, reducing heat islands caused by climate change and improving air quality [151]. Therefore, in urban regions, alternative agricultural systems are a key component in achieving Sustainable Development Goal 11, "Sustainable Cities and Communities" [152].

Changing dietary habits from an animal-based to a more plant-based diet is associated with a contribution to climate change mitigation and sustainable resource use. Accordingly, adopting more sustainable diets, such as a plant-based diet, has a positive impact on FSS [144]. However, there are psychological barriers to shifting to a plant-based diet. Bryant et al. [29] argued that many people are ignorant of the cruelty of livestock farming and deliberately avoid thinking about the issue. When engaging with the issue of animal cruelty, meat eaters are driven by cognitive dissonance, which manifests as motivated reasoning aimed at protecting one's image of oneself and society. Although many people tend to prefer the status quo, meat substitutes are gradually moving from niche to mainstream products [23]. There are also barriers to reducing food waste at the household level. Research shows that a lack of education about the importance of the issue, cultural norms of overconsumption, and inappropriate social marketing prevent consumers from adopting sustainable practices [137].

The analysis of geographical heterogeneity has shown that agricultural inputs, macroeconomic factors, and dietary habits were highly relevant factors in developing countries. Therefore, to increase FSS and to reduce vulnerability to global shocks, public-private partnerships are essential to stimulate private investments in the agri-food sector [108]. Although our results highlighted the global relevance of climate change, Africa experiences its negative effects disproportionately [141]. Some regions endure severe, long-term droughts, crop failures, and famine, while others experience intense rainfall, rising sea levels, and coastal and riparian flooding [61]. Consequently, the effectiveness of agricultural extension services must improve in order to help African farmers adopt technologies that will enable them to adapt to climate change and secure agricultural production [9]. To accomplish this, extension policymakers must collaborate with various stakeholders to develop extension policies that address farmers' needs in light of climate change [2]. The correlation between meat consumption and income remains positive [92]. Consequently, the economic growth of emerging economies, such as China, has led to increased meat consumption [46,137]. In order to avoid threatening FSS, meat consumption could be reduced by eliminating subsidies reflecting the true costs of production, which would make plant-based meat alternatives more competitive [117]. In recent years, the expansion of agricultural production in industrialized countries through alternative agricultural systems, such as rooftop greenhouses and aquaponics, has gained momentum. To foster the innovation and adoption of these technologies, public funding for research [25] and subsidies to make adoption economically more viable are needed [131].

5. Conclusion and policy implications

Crises and conflicts have put FSS back on the political agenda of food import-dependent countries. A systematic identification of the factors affecting FSS, as done in this study, is therefore crucial. From a scientific perspective, FSS appears to be particularly important for developing

countries whose food supply is vulnerable to external shocks, such as the COVID-19 pandemic or the war in Ukraine. Accordingly, scientific interest in the factors affecting FSS peaked during these shocks. The various identified factors affecting FSS were grouped into external events (e.g., climate change, wars, and nuclear disasters), agricultural inputs, macroeconomic factors, dietary habits, trade and agricultural policies, urbanization, alternative agricultural production systems, and food waste and losses.

At first glance, some of the identified factors seemed to be easily influenced by producers and/or consumers for the consequent positive impact on FSS. However, a closer look revealed adverse effects or barriers to change in behavior. For instance, agricultural intensification was positively associated with FSS, but also with adverse environmental effects. Therefore, policymakers should provide incentives for farmers to adopt more sustainable practices that maintain production levels. Adopting more sustainable diets was positively correlated with FSS. However, psychological barriers hinder consumers from doing so. One way policymakers could encourage this shift is by eliminating subsidies on meat, which would make plant-based alternatives more competitive and promote more sustainable food consumption.

Given their vulnerability to global shocks, the analysis of geographical heterogeneity revealed that agricultural inputs, macroeconomic factors, and dietary habits played a major role in influencing FSS in developing countries. Thus, it was not surprising that FSS as a policy goal, as well as subsidies and/or price support, were only relevant in these countries. In order to reduce their vulnerability to global shocks and dependency on food imports, developing countries should focus on increasing FSS. Macroeconomic development is essential for enabling investments in agricultural production and extension services, as well as measures to adapt to climate change and extreme weather events in developing countries. In contrast, industrialized countries can expand FSS by investing in alternative agricultural systems, such as rooftop greenhouses, due to their high level of technological development. This strategy would enhance resilience to climate change and strengthen food security.

Policymakers should therefore carefully consider the circumstances of a country, taking into account the economic costs and benefits, the reliability of trading partners, technological developments and production capacities in agriculture, environmental conditions, consumer preferences, and producer concerns. The debate on the best policy mix to achieve an affordable and stable food supply is controversial. To protect domestic agricultural production, countries may decide to impose high tariffs and strict non-tariff measures on cheap food imports. However, pure reliance on protectionism and FSS increases future potential vulnerability because trade networks are poorly developed. In contrast, pure reliance on trade (i.e., food imports) may jeopardize food security if supply chains are disrupted due to crises or conflicts. Accordingly, FSS policy should be considered a continuum between closed borders for complete FSS on the one hand and complete dependence on trade for food supply on the other. This means that FSS should not be viewed as an "either/or" approach. Our findings also show that the optimal policy mix is context-specific. For instance, climate change and extreme weather events are global challenges. However, due to a low level of economic development, the vulnerability is higher in developing countries. Thus, capacity building and investments in a climate-resilient agriculture are more fundamental in developing countries than in industrialized ones.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

CRediT authorship contribution statement

Christian Ritzel: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A

References of selected studies

Abdullah, M.J., Zhang, Z., Matsubae, K., 2021. Potential for food self-sufficiency improvements through indoor and vertical farming in the Gulf Cooperation Council: Challenges and opportunities from the case of Kuwait. Sustainability 13 (22), 12,553. https://doi.org/10.3390/su132212553.

Alzubi, E., Shbikat, N., Noche, B., 2023. A system dynamics model to improving sustainable performance of the citrus farmers in Jordan Valley. Cleaner Production Letters 4, 100,034. https://doi.org/10.1016/j.clpl.2023.100034.

Anderson, K., 2018. From taxing to subsidizing farmers in China post-1978. China Agricultural Economic Review 10 (1), 36–47. https://doi.org/10.1108/CAER-10–2017–0196.

Anderson, K., Strutt, A., 2014. Growth in densely populated Asia: Implications for primary product exporters. Asia & the Pacific Policy Studies 1 (1), 112–126. https://doi.org/10.1002/app5.14.

Anderson, K., Strutt, A., 2019. Food security policy options for China: Lessons from other countries. Food Policy 49 (1), 50–58. https://doi.org/10.1016/j.foodpol.2014.06.008.

Appendini, K., Liverman, D., 1994. Agricultural policy, climate change and food security in Mexico. Food Policy 19 (2), 149–164. https://doi.org/10.1016/0306–9192(94)90067–1.

Ash, R., 2010. The Chinese economy after 30 years of reform: Perspectives from the agricultural sector. The Copenhagen Journal of Asian Studies 28 (1), 36–62. https://doi.org/10.22439/cjas.v28i1.2861.

Baganz, G.F.M., Timpe, A., Baganz, D., Staaks, G., Hunger, B., Kloas, W., Lohrberg, F., 2022. City or hinterland – Site potentials for upscaled aquaponics in a Berlin case study. npj Urban Sustainability 2 (29. https://doi.org/10.1038/s42949–022–00072-y.

Bainus, A., Yulianti, D., 2018. Food security or food sovereignty? Questioning the paradigm of Indonesian military involvement in agriculture. Central European Journal of International and Security Studies 12 (4), 309–324.

Basnet, S., Wood, A., Röös, E., Jansson, T., Fetzer, I., Gordon, L., 2023. Organic agriculture in a low-emission world: Exploring combined measures to deliver sustainable food system in Sweden. Sustainability Science 18, 501–519. https://doi.org/10.1007/s11625–022–01279–9.

Baydildina, A., Akshinbay, A., Bayetova, M., Mkrytichyan L., Haliepesova, A., Ataev, D., 2000. Agricultural policy reforms and food security in Kazakhstan and Turkmenistan. Food Policy 25 (6), 733–747. https://doi.org/10.1016/S0306–9192(00)00035-X.
Beckmann, V. J., Lenz, R., Volz, P., Weckenbrock, P., 2023. Agricultural production, potential level of self-sufficiency, and climate balances of different food scenarios – A comparative study for the Freiburg region. Naturschutz und Landschaftsplanung 55 (7), 22–29. https://doi.org/10.1399/NuL.2023.07.02.
Beltran-Peña, A., Rosa, L., D'Odorico, P., 2020. Global food self-sufficiency in the 21st century under sustainable intensification of agriculture. Environmental Research Letters 15 (9), 095,004. https://doi.org/10.1088/1748–9326/ab9388.
Beltran-Peña, A., D'Odorico, P., 2022. Future food security in Africa under climate change. Earth's Future 10 (9), e2022EF002651. https://doi.org/10.1029/2022EF002651.
Boyd, M., Wilson, N., 2023. Island refuges for surviving nuclear winter and other abrupt sunlight-reducing catastrophes. Risk Analysis 43 (9), 1824–1842. https://doi.org/10.1111/risa.14072.
Brankov, T., Matkovski, B., 2022. Is a Food Shortage Coming to the Western Balkans? Foods 11 (22), 3672. https://doi.org/10.3390/foods11223672.
Brankov, T., Matkovski, B., Jeremic, M., Duric, I., 2021. Food Self-Sufficiency of the SEE Countries: Is the Region Prepared for a Future Crisis?. Sustainability 13 (16), 8747. https://doi.org/10.3390/su13168747.
Burke, A., 2021. The crossroads of ecotourism dependency, food security and a global pandemic in Galápagos, Ecuador. Sustainability 13 (23), 13,094. https://doi.org/10.3390/su132313094.
Cango, P., Ramos-Martín, J., Falconí, F., 2022. Toward food sovereignty and self-sufficiency in Latin America and the Caribbean: Opportunities for agricultural complementarity. Revista de Economia e Sociologia Rural, 61(1), e251291. https://doi.org/10.1590/1806–9479.2021.251291.
Cerón-Palma, I., Sanyé-Mengual E., Oliver-Solà J., Montero J.I., &., Rieradevall J., 2012. Barriers and Opportunities Regarding the Implementation of Rooftop Eco.Greenhouses (RTEG) in Mediterranean Cities of Europe. Journal of Urban Technology 19 (4), 87–103. https://doi.org/10.1080/10630732.2012.717685.
Chen, Y., Chen, X., Zheng P., Tan, K., Liu S., Chen S., Yang, Z., Wang, X., 2022. Value compensation of net carbon sequestration alleviates the trend of abandoned farmland: A quantification of paddy field system in China based on perspectives of grain security and carbon neutrality. Ecological Indicators 138, 108,815. https://doi.org/10.1016/j.ecolind.2022.108815.
Chuma-Okoro, H., Oluwasemilore, I.A., 2022. Intellectual property rights, agricultural biotechnology and food sufficiency: Strengthening the Nigerian intellectual property legal framework for food self-sufficiency in the aftermath of a global pandemic. International Review of Law, Computers & Technology 36 (1), 48–67. https://doi.org/10.1080/13600869.2021.1997082.
Dalin, C., Qiu, H., Hanasaki, N., Mauzerall, D.L., Rodriguez-Iturbe, I., 2015. Balancing water resource conservation and food security in China. Proceedings of the National Academy of Sciences 112 (15), 4588–4593. https://doi.org/10.1073/pnas.1504345112.
Davis, K.F., Gephart, J.A., Gunda, T., 2016. Sustaining food self-sufficiency of a nation: The case of Sri Lankan rice production and related water and fertilizer demands. Ambio 45 (3), 302–312. https://doi.org/10.1007/s13280–015–0720–2.
Deng, X.Z., Yue, T.X., Liu, Y.J., Dong, J.W., Sun, Z.G., Chen, M.X., Shi, W.J., Zhang, X.Z., Zhao, Z., Yu, Z.Y., 2022. Changes in China's food self-sufficiency rate in the context of a changing dietary structure. Journal of Global Information Management 30 (6), 1–19. https://doi.org/10.4018/JGIM.298666.
Descroix, L., Luxereau, A., Lambert L.A., Ruë, O., Diedhiou, A., Diongue-Niang, A., Dia, A.H., Gangneron, F., Manga, S.P., Diedhiou, A.B., Andrieu, J., Chevalier, P., Faty, B., 2024An interdisciplinary approach to understand the resilience of Agrosystems in the Sahel and West Africa. Sustainability 16 (13), 5555. https://doi.org/10.3390/su16135555.
Doliente, S.S., Samsatli, S., 2021. Integrated production of food, energy, fuels and chemicals from rice crops: Multi-objective optimisation for efficient and sustainable value chains. Journal of Cleaner Production 285, 124,900. https://doi.org/10.1016/j.jclepro.2020.124900.
Duan, X., Meng, Q., Fei, X., Lin, M., Xiao, R., 2021. How much nitrogen does Africa need to feed itself by 2050? Journal of Environmental Management 268, 110,488. https://doi.org/10.1016/j.jenvman.2020.110488.
Ellis, F., 1990. The rice market and its management in Indonesia. IDS Bulletin 21 (3), 44–51. https://doi.org/10.1111/j.1759–5436.1990.mp21003005.x.
Erokhin, V., 2017. Factors influencing food markets in developing countries: An approach to assess sustainability of the food supply in Russia. Sustainability 9 (8), 1313; https://doi.org/10.3390/su9081313.
Firdaus, R.B.R., Leong, Tan, M., Rahmat, S.R., Senevi Gunaratne, M., 2020. Paddy, rice and food security in Malaysia: A review of climate change impacts. Cogent Social Sciences 6 (1), 1818,373. https://doi.org/10.1080/23311886.2020.1818373.
Fuad, A., Mulatsih, S., Purnamawati, H., 2019. Analysis of carrying capacity of agricultural land in supporting sustainable food self-sufficiency in Tegal Regency. IOP Conference Series: Earth and Environmental Science, 399, 012,010. https://doi.org/10.1088/1755–1315/399/1/012010.
Ghose, B., 2014. Food security and food self-sufficiency in China: From past to 2050. Food and Energy Security 3 (2), 86–95. https://doi.org/10.1002/fes3.48.
Groot, J.J.R., de Vries, F.W.T.P., Uithol, P.W.J., 1998. Food supply capacity study at global scale. Nutrient Cycling in Agroecosystems 50, 181–189. https://doi.org/10.1023/A:1009788211315.
Gu, B.J., Ju, X.T., Chang, S.X., Ge, Y., Chang, J., 2017. Nitrogen use efficiencies in Chinese agricultural systems and implications for food security and environmental protection. Regional Environmental Change 17, 1217–1227. https://doi.org/10.1007/s10113–016–1101–5.
Huang, J., Liang, Z., Wu S., Li S., 2019. Grain self-sufficiency capacity in China's metropolitan areas under rapid urbanization: Trends and regional differences from 1990 to 2015. Sustainability 11 (9), 2468. https://doi.org/10.3390/su11092468.
Huang, J.K., Wei, W., Cui, Q., Xie, W., 2017. The prospects for China's food security and imports: Will China starve the world via imports? Journal of Integrative Agriculture 16 (12), 2933–2944. https://doi.org/10.1016/S2095–3119(17)61756–8.
Jeong, O.Y., Park, H.S., Baek, M.K., Kim, W.J., Lee, G.M., Lee, C.M., Bombay, M., Ancheta, M.B., Lee, J.H., 2021. Review of rice in Korea: Current status, future prospects, and comparisons with rice in other countries. Journal of Crop Science and Biotechnology 24, 1–11. https://doi.org/10.1007/s12892–020–00053–6.
Jiang, L., Wu, S., Liu, Y., Yang, C., 2021. Grain security assessment in Bangladesh based on supply-demand balance analysis. PLoS One 16 (5), e0252187. https://doi.org/10.1371/journal.pone.0252187.

Kalt, G., Mayer, A., Haberl, H., Kaufmann, L., Lauk, C., Matej, S., Röös, E., Theurl, M.C., Erb, K.H., 2021. Exploring the option space for land system futures at regional to global scales: The diagnostic agro-food, land use and greenhouse gas emission model BioBaM-GHG 2.0. Ecological Modelling 459, 109,729. https://doi.org/10.1016/j.ecolmodel.2021.109729.
Kamal, T.S., Huang, Y.F., Xu, S., Islam, I., Cui, S.H., 2019. Phosphorus demand for food security: A case study of a food-deficient country. Sustainability 11 (5), 1345. https://doi.org/10.3390/su11051345.
Kovljenic, M., Matkovski, B., Đokić, D., 2024. Competitiveness and Cereal Self-Sufficiency in Western Balkan Countries. Agriculture 14 (9), 1480; https://doi.org/10.3390/agriculture14091480.
Kriewald, S., Pradhan, P., Costa, L., Ros, A.G.C., Kropp, J.P., 2019. Hungry cities: How local food self-sufficiency relates to climate change, diets, and urbanization. Environmental Research Letters 14 (9), 094,007. https://doi.org/10.1088/1748-9326/ab2d56.
Kusumaningrum, R., Darjanto, A., Nurmalina, R., Mulatsih, S., Suprehatin, B., 2024. Supply and demand of beef in Indonesia: A system dynamics approach. IOP Conference Series: Earth and Environmental Science 1341, 012,085. https://doi.org/10.1088/1755-1315/1341/1/012085.
Li, Y., Sun, Z., Accatino, F., 2021. Spatial distribution and driving factors determining local food and feed self-sufficiency in eastern regions of China. Food and Energy Security 10 (3), e296. https://doi.org/10.1002/fes3.296.
Liang, X.Y., Jin, X.B., Xu, X.X., Chen, H.F., Liu, J., Yang, X.H., Xu, W.Y., Sun, R., Han, B., Zhou, Y.K., 2023. Uncertainty in China's food self-sufficiency: A dynamic system assessment. Sustainable Production and Consumption 40, 135–146. https://doi.org/10.1016/j.spc.2023.06.009.
Lu, W.C., Ning-lu, C., Wen-xin, Q., 2017. Modeling the effects of urbanization on grain production and consumption in China. Journal of Integrative Agriculture 16 (6), 1393–1405. https://doi.org/10.1016/S2095–3119(16)61602-7.
Luan, Y., Cui, X., Ferrat, M., 2013. Historical trends of food self-sufficiency in Africa. Food Security 5, 393–405. https://doi.org/10.1007/s12571–013–0260–1.
Luo, N., Meng, Q.F., Feng, P.Y., Qu, Z.R., Yu, Y.H., Liu, D.L. Müller, C., Wang, P., 2023. Nature Communications 14, 2637. https://doi.org/10.1038/s41467–023–38355–2.
Menconi, M.E., Giordano, S., Grohmann, D., 2022. Revisiting global food production and consumption patterns by developing resilient food systems for local communities. Land Use Policy 119, 106,210. https://doi.org/10.1016/j.landusepol.2022.106210.
Mi, X., He, G., Wang, Z., 2022. Comprehensive nitrogen management techniques for wheat self-sufficiency in China. Resources, Conservation and Recycling 178, 106,026. https://doi.org/10.1016/j.resconrec.2021.106026.
Mok, H.F., Williamson, V.G., Grove, J.R., Burry, K., Barker, S.F., Hamilton, A.J., 2014. Strawberry fields forever? Urban agriculture in developed countries: A review. Agronomy for Sustainable Development 34, 21–43. https://doi.org/10.1007/s13593–013–0156–7.
Mukhopadhyay, K., Thomassin, P.J., Zhang, J., 2018. Food security in China at 2050: A global CGE exercise. Journal of Economic Structures 7, 1. https://doi.org/10.1186/s40008–017–0097–4.
Morrissey, M., 1982. Agricultural self-sufficiency: The recent history of an idea. Studies in Comparative International Development 17, 73–95. https://doi.org/10.1007/BF02687278.
Namany, S., Al-Ansari, T., Govindan, R., 2019. Optimisation of the energy, water, and food nexus for food security scenarios. Computers & Chemical Engineering 129, 106,513. https://doi.org/10.1016/j.compchemeng.2019.106513.
Neilson, J., Wright, J., 2017. The state and food security discourses of Indonesia: Feeding the bangsa. Geographical Research 55 (2), 131–143. https://doi.org/10.1111/1745-5871.12210.
Niu, Y., Xie, G., Xiao, Y., Liu, J., Wang, Y., Luo, Q., Zou, H., Gan, S., Qin, K., Huang, M., 2021. Spatiotemporal patterns and determinants of grain self-sufficiency in China. Foods 10 (4), 747. https://doi.org/10.3390/foods10040747.
Onyenwaku, C.E., Ogunfowora, O., Falusi, A.O., 1983. An inter-regional programming model for agricultural planning in Nigeria. Indian Journal of Agricultural Economics 27 (4), 483–493. https://doi.org/10.22004/ag.econ.269869.
Opoku, A., Duff, A., Yahia, M.W., Ekung, S., 2024. Utilisation of green urban space for food sufficiency and the realisation of the sustainable development goals - UK stakeholders perspective. Geography and Sustainability 5 (1), 13–18. https://doi.org/10.1016/j.geosus.2023.10.001.
Ortner, K.M., 1983. I. Forecasts for Austrian agriculture to the year 2000. II. The food and agriculture model for Austria. IIASA Research Report RR-83–22. https://pure.iiasa.ac.at/id/eprint/2154/7/RR-83–022.pdf.
Otsuka, K., Liu, Y., Yamauchi, F., 2013. Factor endowments, wage growth, and changing food self-sufficiency: Evidence from country-level panel data. American Journal of Agricultural Economics, 95 (5), 1252–1258. https://doi.org/10.1093/ajae/aat028.
Overton, J., 1999. Integration or self-sufficiency? Peninsular Malaysia and the rice trade in Southeast Asia. Singapore Journal of Tropical Geography 20 (2), 169–180. https://doi.org/10.1111/1467–9493.00052.
Pingali, P., Abraham, M., 2022. Food systems transformation in Asia – A brief economic history. Agricultural Economics 53 (6), 895–910. https://doi.org/10.1111/agec.12734.
Rutherford, A.S., 1999. Meat and milk self-sufficiency in Asia: Forecast trends and implications. Agricultural Economics 21 (1), 21–39. https://doi.org/10.1016/S0169–5150(99)00008–0.
Sanz, Sanz E., Napoléone, C., Debolini, M., Martinetti D., Moreno Pérez, O., de Benito, C., Mouléry, M., Pinto Correia, T., Filippini, R., Arfa, L., Yacamán-Ochoa, C., 2024. Farmland expansion and intensification do not foster local food self-sufficiency. Insights from the Mediterranean area. Journal of Environmental Management, 351, 119,769. https://doi.org/10.1016/j.jenvman.2023.119769.
Sartorius von Bach, H.J., Kalundu, K.M., 2022. Are SACU countries self-sufficient in cereals? A dynamic panel analysis. Agricultural Economics Research, Policy and Practice in Southern Africa 61 (2), 151-–166. https://doi.org/10.1080/03031853.2022.2052124.
Senbeta, A.F., Worku, W., 2023. Ethiopia's wheat production pathways to self-sufficiency through land area expansion, irrigation advance, and yield gap closure. Heliyon 9 (10), e20720. https://doi.org/10.1016/j.heliyon.2023.e20720.
Qi, X., Huang, X., Song, Y., Wang, D., Zhong, T., Liu, Z., 2023. Grain carbon emission transfer and its spatiotemporal shifts based on the increasing supply-demand separation in China over the past three decades. Science China Earth Sciences 66, 1087–1107. https://doi.org/10.1007/s11430–022–1074-x.
Qi, X., Vitousek, P.M., Liu, L., 2015. Provincial food security in China: A quantitative risk assessment based on local food supply and demand trends. Food Security 7, 621–632. https://doi.org/10.1007/s12571–015–0458–5.
Rui, D., Wenjiao, S., Changhe, L., Hongwei, L., Xiaoli, S., Xiangzheng, D., Jiaying, C., 2022. Future unbalanced-trends of grain supply and demand on the Tibetan Plateau. Journal of Cleaner Production 367, 132,993. https://doi.org/10.1016/j.jclepro.2022.132993.
Simelton, E., 2011. Food self-sufficiency and natural hazards in China. Food Security 3, 35–52. https://doi.org/10.1007/s12571–011–0114–7.

Soltani, A., Alimagham, S.M., Nehbandani, A., Torabi, B., Zeinali, E., Zand, E., Vadez, V., van Loon, M.P., van Ittersum, M.K., 2020. Future food self-sufficiency in Iran: A model-based analysis. Global Food Security 24, 100,351. https://doi.org/10.1016/j.gfs.2020.100351.
Song, S., Hou, Y., Lim, R.B.H., Gaw, L.Y.F., Richards, D.R., Tan, H.T.W., 2022. Comparison of vegetable production, resource-use efficiency and environmental performance of high-technology and conventional farming systems for urban agriculture in the tropical city of Singapore. Science of the Total Environment 807 (2), 150,621. https://doi.org/10.1016/j.scitotenv.2021.150621.
ten Berge, H.F.M., Hijbeek, R., van Loon, M.P., Rurinda, J., Tesfaye, K., Zingore, S., Craufurd P., van Heerwaarden, J., Brentrup, F., Schröder, J.J., Boogaard, H.L., de Groot, H.L.E., van Ittersum, M.K., 2019. Global Food Security 23, 9–21. https://doi.org/10.1016/j.gfs.2019.02.001.
Teneva, L., Free, C.M., Hume, A., Agostini, V.N., Klein, C.J., Watson, R.A., Gaines, S.D., 2023. Small island nations can achieve food security benefits through climate-adaptive blue food governance by 2050. Marine Policy 151, 105,577. https://doi.org/10.1016/j.marpol.2023.105577.
Usman, M., Sawaya, A., Igarashi, M., Gayman, J.J., Dixit, R., 2021. Strained agricultural farming under the stress of youths' career selection tendencies: A case study from Hokkaido (Japan). Humanities & Social Sciences Communications 8, 19. https://doi.org/10.1057/s41599–020–00688–4.
Van Ittersum, M.K., Van Bussel, L.G.J., Wolf, J., Grassini P., Van Wart, J., Guilpart, N., Claessens, L., De Groot, H., Wiebe, K., Mason-D'Croz D., Yang H., Boogaard, H., Van Oort, P.A.J., Van Loon, M.P., Saito, K., Adimo, O., Adjei-Nsiah S., Agali, A., Bala, A., Chikowo, R., Kaizzi K., Kouressy, M., Makoi, J.H.J.R., Ouattara, K., Tesfaye, K., Cassman, K.G., 2016. Can sub-Saharan, Africa feed itself? Proceedings of the National Academy of Sciences 113 (52), 14,964–14,969 https://doi.org/10.1073/pnas.1610359113.
Valiyaveettil, R.R., Jha, G.K., Kathayat, B., 2023. Pushing for self-sufficiency in edible oils in India in the aftermath of recent global events. National Academy Science Letters 46, 483–486. https://doi.org/10.1007/s40009–023–01294-z.
Wei, T.Y., Zhang, T.Y., Cui, X.F., Glomsrod, S., Liu, Y., 2019. Potential influence of climate change on Grain self-sufficiency at the country level considering adaptation measures. Earth's Future 7, 1152–1166. https://doi.org/10.1029/2019EF001213.
Wen, S., Yao, W., Tian, B.T., Xu, L., Liu, Q., Xu, Y., Qi, Z.Q., Yang, Y.D., Zeng, Z.H., Zang, H.D., 2024. Spatiotemporal dynamic of rice production and its carbon footprint in Hainan, China: Implications for food security and environmental sustainability. Journal of Environmental Quality 53 (4), 418–429. https://doi.org/10.1002/jeq2.20590.
Wu, F., Wang, Y., Liu, Y., Liu, Y., Zhang, Y., 2021. Simulated responses of global rice trade to variations in yield under climate change: Evidence from main rice-producing countries. Journal of Cleaner Production 281, 124,690. https://doi.org/10.1016/j.jclepro.2020.124690.
Xie, W., Huang, J., Wang, J., Cui, Q., Robertson, R., Chen, K., 2020. Climate change impacts on China's agriculture: The responses from market and trade. China Economic Review 62, 101,256. https://doi.org/10.1016/j.chieco.2018.11.007.
Xu, S.W., Li, G.Q., Li, Z.M., 2015. China agricultural outlook for 2015–2024 based on China Agricultural Monitoring and Early-warning System (CAMES). Journal of Integrative Agriculture
14 (9), 1889–1902. https://doi.org/10.1016/S2095–3119(15)61149-2.
Yamashita, K., 2006. Food and agriculture problems for Japan and the World in the twenty-first century. Asia-Pacific Review 13 (1), 1–15. https://doi.org/10.1080/13439000600697050.
Yildirim, C., Önen, H.G., 2024. Vulnerabilities of the neoliberal global food system: The Russia-Ukraine War and COVID-19. Journal of Agrarian Change 24 (4), e12601. https://doi.org/10.1111/joac.12601.
Yin, G., Liu, L., Chang, X., Sun, J., 2016. A comprehensive assessment of agricultural intensification scenarios for the Dongting Lake basin in south-central China in 2030. Environmental Science and Pollution Research 23, 14,018–14,033. https://doi.org/10.1007/s11356–016–6510-y.
Yu, W., Li, T., Zhu J., 2019. What determines China's grain imports and self-sufficiency? The role of rising domestic costs and varying world market prices. China & World Economy 27 (5), 1–24. https://doi.org/10.1111/cwe.12299.
Zhan, S., 2022. The political economy of food import and self-reliance in China: 1949–2019. Global Food History 8 (3), 194–212. https://doi.org/10.1080/20549547.2021.2012082.
Zhang, Z., Kattel, G.R., Shang, Y., Wang, G., Chuai, X., Wang, Q., Cui, X., Miao, L., 2023. Steady decline in food self-sufficiency in Africa from 1961 to 2018. Regional Environmental Change 23, 79. https://doi.org/10.1007/s10113–023–02074–7.
Zhao Y., Zhang, Y., Li, X., Qian, C., 2022. Assessment on Land-Water Resources Carrying Capacity of Countries in Central Asia from the Perspective of Self-Supplied Agricultural Products. Land 2022, 11 (2), 278. https://doi.org/10.3390/land11020278.
Zhou, B.B., Aggarwal, R., Wu, J., Lv, L., 2021. Urbanization-associated farmland loss: A macro-micro comparative study in China. Land Use Policy 101, 105,228. https://doi.org/10.1016/j.landusepol.2020.105228.

Appendix B

Table B1
Descriptive statistics of the study characteristic "geographical unit".

Geographical unit	Frequency
1 = Single developing country	61
2 = Group of developing countries	8
3 = Single industrialized country	9
4 = Group of industrialized countries	2
5 = World	5
6 = Other	7
Total	92

Table B2
Descriptive statistics of the study characteristic "product".

Product	Frequency
1 = Multiple grains (e.g., rice, wheat, maize, soy)	25
2 = Single grains	15
3 = Animal-based (meat and dairy products)	3
4 = Plant-based (fruits, vegetables, oils, grains)	8
5 = Animal- and plant-based	26
6 = No specification	15
Total	92

Table B3
Descriptive statistics of the study characteristic "methodological approach".

Methodological approach	Frequency
1 = Quantitative ex-ante	31
2 = Quantitative ex-post	24
3 = Quantitative ex-post and ex-ante	4
4 = Quantitative no time dimension	6
5 = Qualitative narrative	6
6 = Qualitative narrative + descriptive statistics	18
7 = Qualitative interviews	3
Total	92

Table B4
Descriptive statistics of the study characteristic "measurement of FSS".

Measurement of FSS	Frequency
1 = Domestic production/domestic consumption	42
2 = Other definition of FSS	10
3 = No definition of FSS	40
Total	92

Table B5
The frequency of categories and the frequency of factors affecting FSS.

Categories	Freq.	Factors	Freq.
External events	29	Climate change	23
		Extreme weather events	7
		Precipitation	4
		Solar radiation	1
		War	1
		Nuclear disaster	1
		Diseases	1
		Harmful organisms	1
		International inflation/Rising world market prices	1
Agricultural inputs	49	Agricultural area	37
		Fertilizers	20
		Water	18
		Labor	10
		Machinery/Technology	8
		Pesticides	7
		Seeds	7
		Feed	5
		Energy and electricity	5
		Prices/costs	3
		Capital	2
Macroeconomic factors	33	Total population	27
		Economic size	18
		Political stability	3
		Low unemployment rate	1
		Intellectual property rights	1
		Spending research in agriculture	1
		Exchange rate	1
		National inflation	1
		Value added agriculture per capita	1
		Membership in EU	1

(*continued on next page*)

Table B5 (*continued*)

Categories	Freq.	Factors	Freq.
		Independence of a nation	1
		Change in political system	1
Dietary habits	28	Type of diet	25
		Income	8
		Consumer prices	5
		Consumption expenditure	3
		Costs of living	1
Agricultural policy	14	Food self-sufficiency as policy goal	10
		Subsidies and/or price support	4
Trade policy	13	Free trade	9
		Protectionism	6
Urbanization	11	Degree of urbanization	11
Alternative agricultural systems	7	Urban and peri-urban agriculture	6
		Livestock-free agriculture	1
Food waste and losses	5	Level consumption	3
		Level production	2

Data availability

No data were used for the research described in the article.

References

[1] M.J. Abdullah, Z. Zhang, K. Matsubae, Potential for food self-sufficiency improvements through indoor and vertical farming in the Gulf Cooperation Council: challenges and opportunities from the case of Kuwait, Sustainability 13 (22) (2021) 12553, https://doi.org/10.3390/su132212553.

[2] A.E. Agwu, M. Suvedi, C. Chanza, K. Davis, A. Oywaya- Nkurumwa, M. Najjingo Mangheni, P.V.K. Sasidhar, Partnerships for Innovative Research in Africa (PIRA) Research Report, Alliance for African Partnership, Michigan State University, East Lansing, Michigan, USA, 2023.

[3] B.A. Agya, Technological solutions and consumer behaviour in mitigating food waste: a global assessment across income levels, Sustain. Prod. Consum. 55 (2025) 242–256, https://doi.org/10.1016/j.spc.2025.02.020.

[4] N. Ahmad, A. Khan, Food self-sufficiency and food security: a holistic approach, J. Busi. Econ. Opt. 4 (2) (2021) 35–40.

[5] E. Alzubi, N. Shbikat, B. Noche, A system dynamics model to improving sustainable performance of the citrus farmers in Jordan Valley, Clean. Prod. Lett. 4 (2023) 100034, https://doi.org/10.1016/j.clpl.2023.100034.

[6] J. Ammann, C. Liechti, G. Mack, R. Saleh, A food waste information-framing can help promote purchase of suboptimal potatoes, Food Qual. Prefer. 123 (2025) 105338, https://doi.org/10.1016/j.foodqual.2024.105338.

[7] K. Anderson, A. Strutt, Growth in densely populated Asia: implications for primary product exporters, Asia Pac. Pol. Stud. 1 (1) (2014) 112–126, https://doi.org/10.1002/app5.14.

[8] K. Anderson, A. Strutt, Food security policy options for China: lessons from other countries, Food Policy 49 (1) (2019) 50–58, https://doi.org/10.1016/j.foodpol.2014.06.008.

[9] P. Antwi-Agyei, L.C. Stringer, Improving the effectiveness of agricultural extension services in supporting farmers to adapt to climate change: insights from northeastern Ghana, Clim. Risk. Manage. 32 (2021) 100304, https://doi.org/10.1016/j.crm.2021.100304.

[10] K. Appendini, D. Liverman, Agricultural policy, climate change and food security in Mexico, Food Policy 19 (2) (1994) 149–164, https://doi.org/10.1016/0306-9192(94)90067-1.

[11] R. Ash, The Chinese economy after 30 years of reform: perspectives from the agricultural sector, Copenhagen J. Asian Stud. 28 (1) (2010) 36–62, https://doi.org/10.22439/cjas.v28i1.2861.

[12] G.F.M. Baganz, A. Timpe, D. Baganz, G. Staaks, B. Hunger, W. Kloas, F. Lohrberg, City or hinterland – Site potentials for upscaled aquaponics in a Berlin case study, NPJ Urban Sustain. 2 (29) (2022), https://doi.org/10.1038/s42949-022-00072-y.

[13] N. Barbieri, A. Palma, Mapping energy-efficient technological advances in home appliances, Energy Effic. 10 (2017) 693–716, https://doi.org/10.1007/s12053-016-9470-7.

[14] S. Basnet, A. Wood, E. Röös, T. Jansson, I. Fetzer, L. Gordon, Organic agriculture in a low-emission world: exploring combined measures to deliver sustainable food system in Sweden, Sustain. Sci. 18 (2023) 501–519, https://doi.org/10.1007/s11625-022-01279-9.

[15] P. Basu, B.A. Scholten, Technological and social dimensions of the Green Revolution: connecting pasts and futures, Int. J. Agric. Sustain. 10 (2) (2012) 109–116, https://doi.org/10.1080/14735903.2012.674674.

[16] A. Baydildina, A. Akshinbay, M. Bayetova, L. Mkrytichyan, A. Haliepesova, D. Ataev, Agricultural policy reforms and food security in Kazakhstan and Turkmenistan, Food Policy 25 (6) (2000) 733–747, https://doi.org/10.1016/S0306-9192(00)00035-X.

[17] V.J. Beckmann, R. Lenz, P. Volz, P. Weckenbrock, Agricultural production, potential level of self-sufficiency, and climate balances of different food scenarios – A comparative study for the Freiburg region, Naturschutz und Landschaftsplanung 55 (7) (2023) 22–29, https://doi.org/10.1399/NuL.2023.07.02.

[18] J. Bellabry, R. Tirado, A. Leip, F. Weiss, J.P. Lesschen, P. Smith, Glob. Chang. Biol. 19 (1) (2012) 3–18, https://doi.org/10.1111/j.1365-2486.2012.02786.x.

[19] A. Beltran-Peña, P. D'Odorico, Future food security in Africa under climate change, Earth's Future 10 (9) (2022) e2022EF002651, https://doi.org/10.1029/2022EF002651.

[20] A. Beltran-Peña, L. Rosa, P. D'Odorico, Global food self-sufficiency in the 21st century under sustainable intensification of agriculture, Environ. Res. Lett. 15 (9) (2020) 095004, https://doi.org/10.1088/1748-9326/ab9388.

[21] L. Berrang-Ford, A.R. Siders, A. Lesnikowski, A. Paige Fischer, M.W. Callaghan, N. R. Haddaway, K.J. Mach, M. Araos, M.A.R. Shah, M. Wannewitz, D. Doshi, T. Leiter, C. Matavel, J.I. Musah-Surugu, G. Wong-Parodi, P. Antwi-Agyei, I. Ajibade, N. Chauhan, W. Kakemaster, T.Z. Abu, A systematic global stocktake of evidence on human adaptation to climate change, Nat. Clim. Chang. 11 (2021) 989–1000, https://doi.org/10.1038/s41558-021-01170-y.

[22] S. Bolwig, A.N. Tanner, P. Riemann, B. Redlingshöfer, Y. Zhang, Reducing Consumer Food Waste Using Green and Digital Technologies, UNEP DTU Partnership, 2021. https://rucforsk.ruc.dk/ws/portalfiles/portal/81006127/Reducing_Consumer_Food_Waste_Using_Green_and_Digital_Technologies_web.pdf.

[23] F. Boukid, Plant-based meat analogs: from niche to mainstream, Eur. Food Res. Tech. 247 (2020) 297–308, https://doi.org/10.1007/s00217-020-03630-9.

[24] M. Boulet, A. Stott, S. Kneebone, Which behaviours matter? Prioritising food waste reduction behaviours for targeted policy and program approaches, J. Environ. Manage. 345 (2023) 118668, https://doi.org/10.1016/j.jenvman.2023.11866.

[25] A.P. Boyd, P. Zankowski, R. Wheeler, J.R. Stokes-Draut, Y. Chudnovsky, D. Ingram, M. Tijerina, M. Mickens, D. Steward, K. Armstrong, A.S.P. Boggs, B. A. Neely, J.K. Lunney, Y. Luo, Controlled environment agriculture: an opportunity to strengthen interagency research collaboration in the US government, PNAS Nexus. 4 (6) (2025) pgaf155, https://doi.org/10.1093/pnasnexus/pgaf155.

[26] M. Boyd, N. Wilson, Island refuges for surviving nuclear winter and other abrupt sunlight-reducing catastrophes, Risk Anal. 43 (9) (2023) 1824–1842, https://doi.org/10.1111/risa.14072.

[27] T. Brankov, B. Matkovski, Is a food shortage coming to the Western Balkans? Foods 11 (22) (2022) 3672, https://doi.org/10.3390/foods11223672.

[28] T. Brankov, B. Matkovski, M. Jeremic, I. Duric, Food self-sufficiency of the SEE countries: is the region prepared for a future crisis? Sustainability 13 (16) (2021) 8747, https://doi.org/10.3390/su13168747.

[29] C.J. Bryant, A.M.B. Prosser, J. Barnett, Going veggie: identifying and overcoming the social and psychological barriers to veganism, Appetite 169 (2022) 105812, https://doi.org/10.1016/j.appet.2021.105812.

[30] A. Burke, The crossroads of ecotourism dependency, food security and a global pandemic in Galápagos, Ecuador, Sustainability 13 (23) (2021) 13094, https://doi.org/10.3390/su132313094.

[31] S. Busetti, A theory-based evaluation of food waste policy: evidence from Italy, Food Policy 88 (2019) 101749, https://doi.org/10.1016/j.foodpol.2019.101749.

[32] P. Cango, J. Ramos-Martín, F. Falconí, Toward food sovereignty and self-sufficiency in Latin America and the Caribbean: opportunities for agricultural complementarity, Revista de Economia e Sociologia Rural 61 (1) (2022) e251291, https://doi.org/10.1590/1806-9479.2021.251291.

[33] I. Cerón-Palma, E. Sanyé-Mengual, J. Oliver-Solà, J.I. Montero, J. Rieradevall, Barriers and opportunities regarding the implementation of rooftop eco. Greenhouses (RTEG) in Mediterranean Cities of Europe, J. Urban. Technol. 19 (4) (2012) 87–103, https://doi.org/10.1080/10630732.2012.717685.

[34] X. Chen, The role of modern agricultural technologies in improving agricultural productivity and land use efficiency, Front. Plant Sci. 15 (2025), https://doi.org/10.3389/fpls.2025.1675657.
[35] Y. Chen, X. Chen, P. Zheng, K. Tan, S. Liu, S. Chen, Z. Yang, X. Wang, Value compensation of net carbon sequestration alleviates the trend of abandoned farmland: a quantification of paddy field system in China based on perspectives of grain security and carbon neutrality, Ecol. Indic. 138 (2022) 108815, https://doi.org/10.1016/j.ecolind.2022.108815.
[36] H. Chuma-Okoro, I.A. Oluwasemilore, Intellectual property rights, agricultural biotechnology and food sufficiency: strengthening the Nigerian intellectual property legal framework for food self-sufficiency in the aftermath of a global pandemic, Int. Rev. Law Comp. Tech. 36 (1) (2022) 48–67, https://doi.org/10.1080/13600869.2021.1997082.
[37] J. Clapp, Food self-sufficiency and international trade: a false dichotomy?. Technical Note Prepared For the State of Agricultural Commodity Markets 2015–16, 2015. https://openknowledge.fao.org/bitstreams/ea722624-2814-4cc5-ba44-90a79a2c2de5/download.
[38] J. Clapp, Food self-sufficiency: making sense of it, and when it makes sense, Food Policy 66 (2017) 88–96, https://doi.org/10.1016/j.foodpol.2016.12.001.
[39] S. Clune, E. Crossin, K. Verghese, Systematic review of greenhouse gas emissions for different fresh food categories, J. Clean. Prod. 140 (2) (2017) 766–783, https://doi.org/10.1016/j.jclepro.2016.04.082.
[40] J. Corsair, Food Security or self-sufficiency?, 2024. https://ahdb.org.uk/trade-and-policy/food-security-or-self-sufficiency#:~:text=%E2%80%9Cthe%20ability%20of%20a%20region,part%20of%20the%20overall%20picture.
[41] J.W. Creswell, Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research, Pearson Education, Upper Saddle River, NJ, 2002.
[42] C. Dalin, H. Qiu, N. Hanasaki, D.L. Mauzerall, I. Rodriguez-Iturbe, Balancing water resource conservation and food security in China, Proc. Natl. Acad. Sci. 112 (15) (2015) 4588–4593, https://doi.org/10.1073/pnas.1504345112.
[43] K.F. Davis, J.A. Gephart, T. Gunda, Sustaining food self-sufficiency of a nation: the case of Sri Lankan rice production and related water and fertilizer demands, Ambio 45 (3) (2016) 302–312, https://doi.org/10.1007/s13280-015-0720-2.
[44] X.Z. Deng, T.X. Yue, Y.J. Liu, J.W. Dong, Z.G. Sun, M.X. Chen, W.J. Shi, X. Z. Zhang, Z. Zhao, Z.Y. Yu, Changes in China's food self-sufficiency rate in the context of a changing dietary structure, J. Glob. Inf. Manage. 30 (6) (2022) 1–19, https://doi.org/10.4018/JGIM.298666.
[45] S.S. Doliente, S. Samsatli, Integrated production of food, energy, fuels and chemicals from rice crops: multi-objective optimisation for efficient and sustainable value chains, J. Clean. Prod. 285 (2021) 124900, https://doi.org/10.1016/j.jclepro.2020.124900.
[46] J. Doyle, A. Richardson, The moderating role of post-materialism in the relationship between income and red meat consumption, Int. J. Sociol. 55 (4) (2025) 303–321, https://doi.org/10.1080/00207659.2025.2473207.
[47] X. Duan, Q. Meng, X. Fei, M. Lin, R. Xiao, How much nitrogen does Africa need to feed itself by 2050? J. Environ. Manage. 268 (2021) 110488 https://doi.org/10.1016/j.jenvman.2020.110488.
[48] N.K. Dubash, A.V. Pillai, C. Flachsland, K. Harrison, K. Hochstetler, M. Lockwood, R. MacNeil, M. Mildenberger, M. Paterson, F. Teng, F. Tyler, National climate institutions complement targets and policies, Science (1979) 374 (6568) (2021) 690–693, https://doi.org/10.1126/science.abm1157.
[49] N. El Benni, R. Finger, S. Mann, Effects of agricultural policy reforms and farm characteristics on income risk in Swiss agriculture, Agricult. Finan. Rev. 72 (3) (2012) 301–324, https://doi.org/10.1108/00021461211277204.
[50] F. Ellis, The rice market and its management in Indonesia, IDS Bull. 21 (3) (1990) 44–51, https://doi.org/10.1111/j.1759-5436.1990.mp21003005.x.
[51] V. Erokhin, Factors influencing food markets in developing countries: an approach to assess sustainability of the food supply in Russia, Sustainability 9 (8) (2017) 1313, https://doi.org/10.3390/su9081313.
[52] EU (European Union), State of Food Security in the EU: A qualitative Assessment of Food Supply and Food Security in the EU within the Framework of the EFSCM, 2023. https://agriculture.ec.europa.eu/system/files/2023-11/efscm-assessment-autumn-2023_en.pdf.
[53] EU (European Union), Greening Agriculture, a, 2025, https://www.consilium.europa.eu/en/policies/greening-agriculture/.
[54] EU (European Union), Sustainable Development in EU Trade Agreements, b, 2025, https://policy.trade.ec.europa.eu/development-and-sustainability/sustainable-development/sustainable-development-eu-trade-agreements_en.
[55] M. Faaroq, A. Rehman, M. Pisante, Sustainable agriculture and food security, in: M. Faaroq, M. Pisante (Eds.), Innovations in Sustainable Agriculture, 2019, https://doi.org/10.1007/978-3-030-23169-9.
[56] FAO (Food and Agriculture Organization of the United Nations), Food security. Policy Brief June 2006, 2006. https://www.fao.org/fileadmin/templates/faoitaly/documents/pdf/pdf_Food_Security_Cocept_Note.pdf.
[57] FAO (Food and Agriculture Organization of the United Nations), FAO Statistical Yearbook 2012 – World Food and Agriculture, 2012. https://www.fao.org/4/i2490e/i2490e00.htm.
[58] FAO (Food and Agriculture Organization of the United Nations), Ecosystem-based Adaptation in the Agriculture Sector – A nature-Based Solution (NbS) For Building the Resilience of the Food and Agriculture Sector to Climate Change, 2020. https://openknowledge.fao.org/server/api/core/bitstreams/c98872f8-0d2c-47aa-b916-ea8c3743df00/content.
[59] FAO (Food and Agriculture Organization of the United Nations), Addressing Food Security Challenges Faced By Near East and North Africa Region Due to the Ukraine Crisis, a, 2022, https://doi.org/10.4060/cb9926en.
[60] FAO (Food and Agriculture Organization of the United Nations), The state of agricultural commodity markets 2022. The Geography of Food and Agricultural trade: Policy approaches For Sustainable Development, 2022, https://doi.org/10.4060/cc0471en.
[61] L. Fonjong, F. Matose, D.A. Sonnenfeld, Climate change in Africa: impacts, adaptation, and policy responses, Glob. Environ. Change 89 (2024) 102912, https://doi.org/10.1016/j.gloenvcha.2024.102912.
[62] E. Gage, X. Wang, B. Xu, A. Foster, J. Evans, L.A. Terry, N. Falagán, Reducing food loss and waste contributes to energy, economic and environmental sustainability, J. Clean. Prod. 451 (2024) 142068, https://doi.org/10.1016/j.jclepro.2024.142068.
[63] GAIN (The Columbia Climate School, Cornell University, and FAO), Cereal Import Dependency Ratio (%), 2025. https://www.foodsystemsdashboard.org/indicators/drivers/globalization-and-trade/cereal-import-dependency-ratio-3-year-average/bar-chart.
[64] I. Garcia-Herrero, D. Hoehm, M. Margallo, J. Laso, A. Bala, L. Batlle-Bayer, P. Fullana, I. Vazquez-Rowe, M.J. Gonzalez, M.J. Durá, C. Sarabia, R. Abajas, F. J. Arno-Setien, A. Quiñones, A. Irabien, R. Aldaco, On the estimation of potential food waste reduction to support sustainable production and consumption policies, Food Policy 80 (2018) 24–38, https://doi.org/10.1016/j.foodpol.2018.08.007.
[65] S. Getahun, H. Kefale, Y. Gelaye, Application of precision agriculture technologies for sustainable crop production and environmental sustainability: a systematic review, Sci. World J. 2024 (2024) 2126734, https://doi.org/10.1155/2024/2126734.
[66] B. Ghose, Food security and food self-sufficiency in China: from past to 2050, Food Energy Secur. 3 (2) (2014) 86–95, https://doi.org/10.1002/fes3.48.
[67] A. Greenfeld, N. Becker, J.F. Bornman, S. Spatari, D.L. Angel, Is aquaponics good for the environment?—Evaluation of environmental impact through life cycle assessment studies on aquaponics systems, Aquacult. Int. 30 (2022) 305–322, https://doi.org/10.1007/s10499-021-00800-8.
[68] B.J. Gu, X.T. Ju, S.X. Chang, Y. Ge, J. Chang, Nitrogen use efficiencies in Chinese agricultural systems and implications for food security and environmental protection, Reg. Environ. Change 17 (2017) 1217–1227, https://doi.org/10.1007/s10113-016-1101-5.
[69] S.F. Hamilton, T.J. Richards, Food policy and household food waste, Am. J. Agric. Econ. 101 (2) (2019) 600–614, https://doi.org/10.1093/ajae/aay109.
[70] K. Hopewell, M.E. Margulis, Global trade rules threaten food security amid climate shocks, Earth Syst. Govern. 18 (2023) 100198, https://doi.org/10.1016/j.esg.2023.100198.
[71] L.G. Horlings, T.K. Marsden, Towards the real green revolution? Exploring the conceptual dimensions of a new ecological modernisation of agriculture that could 'feed the world, Glob. Environ. Chang. 21 (2011) 441–452, https://doi.org/10.1016/j.gloenvcha.2011.01.004.
[72] J.K. Huang, W. Wei, Q. Cui, W. Xie, The prospects for China's food security and imports: will China starve the world via imports? J. Integr. Agricult. 16 (12) (2017) 2933–2944, https://doi.org/10.1016/S2095-3119(17)61756-8.
[73] X. Irz, J.D. Jensen, P. Leroy, V. Réquillart, L.G. Soler, Promoting climate-friendly diets: what should we tell consumers in Denmark, Finland and France? Environ. Sci. Policy 99 (2019) 169–177, https://doi.org/10.1016/j.envsci.2019.05.006.
[74] A. Janousek, S. Markey, M. Roseland, We see a real opportunity around food waste": exploring the relationship between on-farm food waste and farm characteristics, Agroecol. Sustain. Food Syst. 42 (8) (2018) 933–960, https://doi.org/10.1080/21683565.2018.1468381.
[75] L. Jiang, S. Wu, Y. Liu, C. Yang, Grain security assessment in Bangladesh based on supply-demand balance analysis, PLoS One 16 (5) (2021) e0252187, https://doi.org/10.1371/journal.pone.0252187.
[76] R. Jones, J. Llewellyn, Maintaining stable macroeconomic conditions, Natl. Inst. Econ. Rev. 250 (2019) 7–14. https://www.rhysmichaelbidder-economist.com/_files/ugd/6143e8_b5b31a20dbae44ab9d08459385580eb5.pdf#page=8.
[77] G. Kalt, A. Mayer, H. Haberl, L. Kaufmann, C. Lauk, S. Matej, E. Röös, M. C. Theurl, K.H. Erb, Exploring the option space for land system futures at regional to global scales: the diagnostic agro-food, land use and greenhouse gas emission model BioBaM-GHG 2.0, Ecol. Modell. 459 (2021) 109729, https://doi.org/10.1016/j.ecolmodel.2021.109729.
[78] T.B. Karki, S.K. Sah, R.B. Thapa, A.J. McDonald, A.S. Davis, Identifying pathways for improving household food self-sufficiency outcomes in the hills of Nepal, PLoS One 10 (6) (2015) e0127513, https://doi.org/10.1371/journal.pone.0127513.
[79] L. Kaufmann, A. Mayer, S. Matej, G. Kalt, C. Lauk, M.C. Theurl, K.H. Erb, Regional self-sufficiency: a multi-dimensional analysis relating agricultural production and consumption in the European Union, Sustain. Prod. Consum. 34 (2022) 12–25, https://doi.org/10.1016/j.spc.2022.08.014.
[80] M. Kovljenic, B. Matkovski, D. Đokić, Competitiveness and cereal self-sufficiency in Western Balkan countries, Agriculture 14 (9) (2024) 1480, https://doi.org/10.3390/agriculture14091480.
[81] S. Kriewald, P. Pradhan, L. Costa, A.G.C. Ros, J.P. Kropp, Hungry cities: how local food self-sufficiency relates to climate change, diets, and urbanization, Environ. Res. Lett. 14 (9) (2019) 094007, https://doi.org/10.1088/1748-9326/ab2d56.
[82] R. Kusumaningrum, A. Darjanto, R. Nurmalina, S. Mulatsih, B. Suprehatin, Supply and demand of beef in Indonesia: a system dynamics approach, in: IOP Conference Series: Earth and Environmental Science 1341, 2024 012085, https://doi.org/10.1088/1755-1315/1341/1/012085.
[83] B. Li, C. Chen, B. Hu, Governing urbanization and the new urbanization plan in China, Environ. Urban. 28 (2) (2016) 515–534, https://doi.org/10.1177/0956247816647345.

[84] Y. Li, Z. Sun, F. Accatino, Spatial distribution and driving factors determining local food and feed self-sufficiency in eastern regions of China, Food Energy Secur. 10 (3) (2021) e296, https://doi.org/10.1002/fes3.296.
[85] X.Y. Liang, X.B. Jin, X.X. Xu, H.F. Chen, J. Liu, X.H. Yang, W.Y. Xu, R. Sun, B. Han, Y.K. Zhou, Uncertainty in China's food self-sufficiency: a dynamic system assessment, Sustain. Prod. Consum. 40 (2023) 135–146, https://doi.org/10.1016/j.spc.2023.06.009.
[86] W.C. Lu, C. Ning-lu, Q. Wen-xin, Modeling the effects of urbanization on grain production and consumption in China, J. Integrat. Agricult. 16 (6) (2017) 1393–1405, https://doi.org/10.1016/S2095-3119(16)61602-7.
[87] Y. Luan, X. Cui, M. Ferrat, Historical trends of food self-sufficiency in Africa, Food Secur. 5 (2013) 393–405, https://doi.org/10.1007/s12571-013-0260-1.
[88] N. Luo, Q.F. Meng, P.Y. Feng, Z.R. Qu, Y.H. Yu, D.L. Liu, C. Müller, P. Wang, Nat. Commun. 14 (2023) 2637, https://doi.org/10.1038/s41467-023-38355-2.
[89] C. MacLaren, A. Mead, D. van Balen, L. Claessens, A. Etana, J. de Haan, W. Haagsma, O. Jäck, T. Keller, J. Labuschagne, A. Myrbeck, M. Necpalova, G. Nziguheba, J. Six, J. Strauss, P.A. Swanepoel, C. Thierfelder, C. Topp, F. Tshuma, H. Verstegen, R. Walker, C. Watson, M. Wesselink, J. Storkey, Long-term evidence for ecological intensification as a pathway to sustainable agriculture, Nat. Sustain. 5 (2022) 770–779, https://doi.org/10.1038/s41893-022-00911-x.
[90] J.Z. Manyike, T. Ningi, J.P. Mokhaukhau, L. Maka, Performance and conceptual structure of climate-smart agriculture research: a bibliometric analysis (2010–2023), Front. Sustain. Food Syst. 9 (2025), https://doi.org/10.3389/fsufs.2025.1499982.
[91] M.E. Menconi, S. Giordano, D. Grohmann, Revisiting global food production and consumption patterns by developing resilient food systems for local communities, Land Use Policy 119 (2022) 106210, https://doi.org/10.1016/j.landusepol.2022.106210.
[92] A.B. Milford, C. Le Mouël, B.L. Bodirsky, S. Rolinski, Drivers of meat consumption, Appetite 141 (2019) 104313, https://doi.org/10.1016/j.appet.2019.06.005.
[93] D. Moher, A. Liberati, J. Tetzlaff, D.G. Altman, Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement, PLoS Med. 6 (7) (2009) e1000097, https://doi.org/10.1371/journal.pmed.1000097.
[94] O. Mont, M. Lehner, C. Dalhammer, Sustainable consumption through policy intervention—A review of research themes, Front. Sustain. 3 (2022), https://doi.org/10.3389/frsus.2022.921477.
[95] M. Morrissey, Agricultural self-sufficiency: the recent history of an idea, Stud. Comp. Int. Dev. 17 (1982) 73–95, https://doi.org/10.1007/BF02687278.
[96] S. Namany, T. Al-Ansari, R. Govindan, Optimisation of the energy, water, and food nexus for food security scenarios, Comput. Chem. Eng. 129 (2019) 106513, https://doi.org/10.1016/j.compchemeng.2019.106513.
[97] J. O'Connor, S.A. Hoang, L. Bradney, S. Dutta, X. Xiong, D.C.W. Tsang, K. Ramadass, A. Vinu, M.B. Kirkham, N.S. Bolan, A review on the valorisation of food waste as a nutrient source and soil amendment, Environ. Poll. 272 (2021) 115985, https://doi.org/10.1016/j.envpol.2020.115985.
[98] C.E. Onyenwaku, O. Ogunfowora, A.O. Falusi, An inter-regional programming model for agricultural planning in Nigeria, Ind. J. Agricult. Econ. 27 (4) (1983) 483–493, https://doi.org/10.22004/ag.econ.269869.
[99] K.M. Ortner, IIASA Research Report RR-83-22, 1983. https://pure.iiasa.ac.at/id/eprint/2154/7/RR-83-022.pdf.
[100] K. Otsuka, Y. Liu, F. Yamauchi, Factor endowments, wage growth, and changing food self-sufficiency: evidence from country-level panel data, Am. J. Agric. Econ. 95 (5) (2013) 1252–1258, https://doi.org/10.1093/ajae/aat028.
[101] D. Pimentel, Green revolution agriculture and chemical hazards, Sci. Total. Environ. 188 (Supplement) (1996) S86–S98, https://doi.org/10.1016/0048-9697(96)05280-1.
[102] J. Overton, Integration or self-sufficiency? Peninsular Malaysia and the rice trade in Southeast Asia, Singap. J. Trop. Geogr. 20 (2) (1999) 169–180, https://doi.org/10.1111/1467-9493.00052.
[103] D. Pimentel, M. Pimentel, Sustainability of meat-based and plant-based diets and the environment, Am. J. Clin. Nutr. 78 (3) (2003) 660S–663S, https://doi.org/10.1093/ajcn/78.3.660S.
[104] P.L. Pingali, Green revolution: impacts, limits, and the path ahead, Proc. Natl. Acad. Sci. 109 (31) (2012) 12302–12308, https://doi.org/10.1073/pnas.091295310.
[105] P. Pingali, M. Abraham, Food systems transformation in Asia – A brief economic history, Agricult. Econ. 53 (6) (2022) 895–910, https://doi.org/10.1111/agec.12734.
[106] A.S. Rutherford, Meat and milk self-sufficiency in Asia: forecast trends and implications, Agricult. Econ. 21 (1) (1999) 21–39, https://doi.org/10.1016/S0169-5150(99)00008-0.
[107] E. Pisani, Some Socio-Economic Consequences of the Green Revolution, 2006. MPRA Paper No. 24977, https://mpra.ub.uni-muenchen.de/24977/1/MPRA_paper_24977.pdf.
[108] C. Poulton, J. Macartney, Can public–private partnerships leverage private investment in agricultural value chains in Africa? A preliminary review, World Dev. 40 (1) (2012) 96–109, https://doi.org/10.1016/j.worlddev.2011.05.017.
[109] X. Qi, X. Huang, Y. Song, D. Wang, T. Zhong, Z. Liu, Grain carbon emission transfer and its spatiotemporal shifts based on the increasing supply-demand separation in China over the past three decades, Sci. China Earth. Sci. 66 (2023) 1087–1107, https://doi.org/10.1007/s11430-022-1074-x.
[110] X. Qi, P.M. Vitousek, L. Liu, Provincial food security in China: a quantitative risk assessment based on local food supply and demand trends, Food Secur. 7 (2015) 621–632, https://doi.org/10.1007/s12571-015-0458-5.
[111] M. Raj, M. Prahadeeswaran, Revolutionizing agriculture: a review of smart farming technologies for a sustainable future, Discov. Appl. Sci. 7 (2025) 937, https://doi.org/10.1007/s42452-025-07561-6.
[112] D. Rui, S. Wenjiao, L. Changhe, L. Hongwei, S. Xiaoli, D. Xiangzheng, C. Jiaying, Future unbalanced-trends of grain supply and demand on the Tibetan Plateau, J. Clean. Prod. 367 (2022) 132993, https://doi.org/10.1016/j.jclepro.2022.132993.
[113] J.M. Saatz, Conceptual issues in analyzing the economics of agricultural and food self-sufficiency, in: F.J. Ruppel, E.D. Kellogg (Eds.), National and Regional Self-Sufficiency Goals: Implications for International Agriculture, Lynne Rienner Publishers, Boulder and London, 1991.
[114] J. Sabaté, S. Soret, Sustainability of plant-based diets: back to the future, Am. J. Clin. Nutr. 100 (Supplement 1) (2014) 4765–4825, https://doi.org/10.3945/ajcn.113.071522.
[115] D. Sanjuan-Delmás, P. Llorach-Massana, A. Nadal, M. Ercilla-Montserrat, P. Muñoz, J.I. Montero, Al. Josa, X. Gabarrell, J. Rieradevall, Environmental assessment of an integrated rooftop greenhouse for food production in cities, J. Clean. Prod. 177 (2018) 326–337, https://doi.org/10.1016/j.jclepro.2017.12.147.
[116] M. Seymour, A. Utter, Veganic farming in the United States: farmer perceptions, motivations, and experiences, Agric. Human. Val. 38 (2021) 1139–1159, https://doi.org/10.1007/s10460-021-10225-x.
[117] M. Siegrist, F. Michel, C. Hartmann, The shift from meat to plant-based proteins: consumers and public policy, Curr. Opin. Food Sci. 58 (2024) 101182, https://doi.org/10.1016/j.cofs.2024.101182.
[118] E. Simelton, Food self-sufficiency and natural hazards in China, Food Secur. 3 (2011) 35–52, https://doi.org/10.1007/s12571-011-0114-7.
[119] Y. Slater, I. Finkelshtain, A.M. Troen, I. Kan, Economic analysis of food self-sufficiency: modeling and application to the case of Israel, Food Policy 136 (2025) 102979, https://doi.org/10.1016/j.foodpol.2025.102979.
[120] A. Soltani, S.M. Alimagham, A. Nehbandani, B. Torabi, E. Zeinali, E. Zand, V. Vadez, M.P. van Loon, M.K. van Ittersum, Future food self-sufficiency in Iran: a model-based analysis, Glob. Food Sec. 24 (2020) 100351, https://doi.org/10.1016/j.gfs.2020.100351.
[121] B. Soriano, A. Garrido, How important is economic growth for reducing undernourishment in developing countries? Food Policy 63 (2016) 87–101, https://doi.org/10.1016/j.foodpol.2016.07.004.
[122] H.J. Sartorius von Bach, K.M. Kalundu, Are SACU countries self-sufficient in cereals? A dynamic panel analysis, Agricult. Econ. Res. Pol. Pract. South. Afr. 61 (2) (2022) 151–166, https://doi.org/10.1080/03031853.2022.2052124.
[123] K. Specht, T. Weith, K. Swoboda, R. Siebert, Socially acceptable urban agriculture businesses, Agron. Sustain. Dev. 36 (2016) 17, https://doi.org/10.1007/s13593-016-0355-0, 2016.
[124] P.C. Struik, T.W. Kuyper, Sustainable intensification in agriculture: the richer shade of green: a review, Agron. Sustain. Dev. 37 (2017) 39, https://doi.org/10.1007/s13593-017-0445-7.
[125] G.R. Squire, C. Hawes, T.A. Valentine, M.W. Young, Degradation rate of soil function varies with trajectory of agricultural intensification, Agric. Ecosyst. Environ. 202 (2015) 160–167, https://doi.org/10.1016/j.agee.2014.12.004.
[126] S. Stacy, Can a complicated "consensus" survive a dose of populist poison? Exploring the potential impact of Brexit and Trumpism on the developed country approach to trade law and policy, Law Dev. Rev. 14 (2) (2021) 689–722, https://doi.org/10.1515/ldr-2021-0048.
[127] L. Teneva, C.M. Free, A. Hume, V.N. Agostini, C.J. Klein, R.A. Watson, S. D. Gaines, Small island nations can achieve food security benefits through climate-adaptive blue food governance by 2050, Mar. Policy 151 (2023) 105577, https://doi.org/10.1016/j.marpol.2023.105577.
[128] A.M. Thow, D. Patay, Enhancing Coherence Between Agricultural, Trade, and Health Policy Objectives in the Climate Crisis Context, 2025. https://tessforum.org/latest/enhancing-coherence-between-agricultural-trade-and-health-policy-objectives-in-the-climate-crisis-context.
[129] A. Tleuberdinova, N. Nurlanova, F. Alzhanova, P. Salibekova, Food security and self-sufficiency as a factor of country's sustainable development: assessment methods and solutions, Discov. Sustain. 6 (2025) 50, https://doi.org/10.1007/s43621-025-00849-y.
[130] UN (United Nations), World Economic Situation and Prospects 2024, 2024. https://www.un.org/development/desa/dpad/wp-content/uploads/sites/45/WESP_2024_Web.pdf.
[131] UNDP (United Nations Development Programme), Controlled Environment Agriculture for Sustainable Development, 2025. https://www.undp.org/sites/g/files/zskgke326/files/2025-01/controlled_environment_agriculture_for_sustainable_development.pdf.
[132] UNICEF (United Nations Convention on the Rights of the Child), As the War in Ukraine continues, Millions of Children in the Middle East and North Africa at Increased Risk of Malnutrition amid Food Price Hikes, 2022. https://www.unicef.org/press-releases/war-ukraine-continues-millions-children-middle-east-and-north-africa-increased-risk.
[133] M. Usman, A. Sawaya, M. Igarashi, J.J. Gayman, R. Dixit, Strained agricultural farming under the stress of youths' career selection tendencies: a case study from Hokkaido (Japan), Hum. Soc. Sci. Commun. 8 (2021) 19, https://doi.org/10.1057/s41599-020-00688-4.
[134] R.R. Valiyaveettil, G.K. Jha, B. Kathayat, Pushing for self-sufficiency in edible oils in India in the aftermath of recent global events, Natl. Acad. Sci. Lett. 46 (2023) 483–486, https://doi.org/10.1007/s40009-023-01294-z.
[135] M.K. Van Ittersum, L.G.J. Van Bussel, J. Wolf, P. Grassini, J. Van Wart, N. Guilpart, L. Claessens, H. De Groot, K. Wiebe, D. Mason-D'Croz, H. Yang,

H. Boogaard, P.A.J. Van Oort, M.P. Van Loon, K. Saito, O. Adimo, S. Adjei-Nsiah, A. Agali, A. Bala, R. Chikowo, K. Kaizzi, M. Kouressy, J.H.J.R. Makoi, K. Ouattara, K. Tesfaye, K.G. Cassman, Can sub-Saharan, Africa feed itself? Proc. Natl. Acad. Sci. 113 (52) (2016) 14964–14969, https://doi.org/10.1073/pnas.1610359113.

[136] A. Wakefield, S. Axon, I'm a bit of a waster": identifying the enablers of, and barriers to, sustainable food waste practices, J. Clean. Prod. 275 (2020) 122803, https://doi.org/10.1016/j.jclepro.2020.122803.

[137] H.H. Wang, The perspective of meat and meat-alternative consumption in China, Meat. Sci. 194 (2022) 108982, https://doi.org/10.1016/j.meatsci.2022.108982.

[138] T.Y. Wei, T.Y. Zhang, X.F. Cui, S. Glomsrod, Y. Liu, Potential influence of climate change on Grain self-sufficiency at the country level considering adaptation measures, Earth's Future 7 (2019) 1152–1166, https://doi.org/10.1029/2019EF001213.

[139] S. Wen, W. Yao, B.T. Tian, L. Xu, Q. Liu, Y. Xu, Z.Q. Qi, Y.D. Yang, Z.H. Zeng, H. D. Zang, Spatiotemporal dynamic of rice production and its carbon footprint in Hainan, China: implications for food security and environmental sustainability, J. Environ. Qual. 53 (4) (2024) 418–429, https://doi.org/10.1002/jeq2.20590.

[140] C. Willersinn, P. Mouron, G. Mack, M. Siegrist, Food loss reduction from an environmental, socio-economic and consumer perspective – The case of the Swiss potato market, Waste Management 59 (2017) 451–464, https://doi.org/10.1016/j.wasman.2016.10.007.

[141] WMO (World Meterological Organization), Africa Suffers Disproportionately from Climate Change, 2023. https://wmo.int/media/news/africa-suffers-disproportionately-from-climate-change.

[142] L. Xiao, W. Peng, W. Yu, Z. Xin, S. Niu, Y. Qu, Sustainable intensification to coordinate agricultural efficiency and environmental protection: a systematic review based on metrological visualization, J. Land Use Sci. 16 (3) (2021) 313–338, https://doi.org/10.1080/1747423X.2021.1922524.

[143] S.W. Xu, G.Q. Li, Z.M. Li, China agricultural outlook for 2015-2024 based on China Agricultural Monitoring and Early-warning System (CAMES), J. Integr. Agricult. 14 (9) (2015) 1889–1902, https://doi.org/10.1016/S2095-3119(15)61149-2.

[144] X. Yang, Q. Gao, H. Duan, M. Zhu, S. Wang, GHG mitigation strategies on China's diverse dish consumption are key to meet the Paris Agreement targets, Nat. Food 5 (2024) 365–377, https://doi.org/10.1038/s43016-024-00978-z.

[145] A. Zimmermann, G. Rapsomanikis, Trade and sustainable food systems. FAO Food Systems Summit Brief 2021, 2021. https://knowledge4policy.ec.europa.eu/sites/default/files/UNFSS-brief-Trade-and-sustainable-food-systems_18June_mr.pdf.

[146] C. Yildirim, H.G. Önen, Vulnerabilities of the neoliberal global food system: the Russia-Ukraine War and COVID-19, J. Agrar. Change 24 (4) (2024) e12601, https://doi.org/10.1111/joac.12601.

[147] J. Pattenden, L. Campling, E.C. Ballivián, C. Gras, J. Lerche, B. O'Laughlin, C. Oya, H. Pérez-Niño, S. Sinha, Introduction: Covid-19 and the conditions and struggles of agrarian classes of labour, J. Agrar. Change 21 (3) (2021) 582–590, https://doi.org/10.1111/joac.12440.

[148] H.F.M. ten Berge, R. Hijbeek, M.P. van Loon, J. Rurinda, K. Tesfaye, S. Zingore, P. Craufurd, J. van Heerwaarden, F. Brentrup, J.J. Schröder, H.L. Boogaard, H.L.E. de Groot, M.K. van Ittersum, Maize crop nutrient input requirements for food security in sub-Saharan Africa. Glob. Food Secur. 23 (2019) 9–21, https://doi.org/10.1016/j.gfs.2019.02.001.

[149] K.M. Ortner, I. Forecasts for Austrian agriculture to the year 2000. II. The food and agriculture model for Austria. IIASA Research Report RR-83–22, 1983. https://pure.iiasa.ac.at/id/eprint/2154/7/RR-83–022.pdf.

[150] European Union (EU). Farm to Fork Strategy: For a fair, healthy and environmentally-friendly food system, 2020. https://food.ec.europa.eu/system/files/2020-05/f2f_action-plan_2020_strategy-info_en.pdf.

[151] R. Gunapala, R. Gangahagedara, W.C.S. Wanasinghe, A.U. Samaraweera, A. Gamage, C. Rathnayaka, Z. Hameed, Z.A. Baki, T. Madhujith, O. Merah, Urban agriculture: A strategic pathway to building resilience and ensuring sustainable food security in cities, Farm. Syst. 3 (3) (2025) 100150, https://doi.org/10.1016/j.farsys.2025.100150.

[152] H.J. Thwaites, I.V. Hume, T.R. Cavagnaro, The case for urban agriculture: opportunities for sustainable development, Urban For. Urban Green. 110 (2025) 128861, https://doi.org/10.1016/j.ufug.2025.128861.

[153] D. Pieper, L. Puljak, Language restrictions in systematic reviews should not be imposed in the search strategy but in the eligibility criteria if necessary, J. Clin. Epidemiol. (2021) 146–147, https://doi.org/10.1016/j.jclinepi.2020.12.027.