Systematic review on impacts of changing food supply and food prices on dietary patterns and nutritional status in low- and middle-income countries

Systematic Review

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Nutrition Research Facility
Knowledge and Research for Nutrition

About the Nutrition Research Facility

The Knowledge and Research for Nutrition project of the European Commission (2020-2026) aims to provide improved knowledge and evidence for policy and programme design, management and monitoring & evaluation in order to reach better nutrition outcomes.

The project is implemented by Agrinatura - the European Alliance on Agricultural Knowledge for Development – which has established a Nutrition Research Facility, pooling expertise from European academia and having the ability to mobilise internationally renowned scientific networks and research organisations from partner countries.

The Nutrition Research Facility provides expert advice to the European Commission and to the European Union (EU) Member States and Partner Countries.

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Content

List of Acronyms

Acronym	Description
AMSTAR 2	A MeaSurement Tool to Assess Systematic Reviews 2
CCT	Conditional cash transfer
CF	Child feeding
CHVs	Community Health Volunteers
COVID-19	Coronavirus disease 2019
DRC	Democratic Republic of Congo
EC	European Commission
FAO	Food and Agriculture Organization of the United Nations
GAM	Global Acute Malnutrition
HAZ	Height for age z-score
Hb	Haemoglobin
HLPE	High-Level Panel of Experts
HQ-LNS	High-quantity lipid-based nutrient supplement
iCCM	Integrated community case management
IDPs	Internally displaced persons
IYCF	Infant and young child feeding
LMIC	Low and middle-income countries
LNS	Lipid-based nutrient supplement
MAM	Moderate acute malnutrition
MUAC	Mid-upper arm circumference
NRF	Nutrition Research Facility
PDS	Public Distribution System
PICO	Population, Intervention, Comparison, and Outcome
PTT	Programa de transferencia de tierras
RNI	Recommended nutrient intake
RUSF	Ready-to-use supplementary food
RUTF	Ready-to-use therapeutic food
SAM	Severe acute malnutrition
SARS	Severe acute respiratory syndrome
SCC	Shocks, Conflicts and Crises
SC/SC+	Super Cereal / Super Cereal Plus
SQ-LNS	Small-quantity lipid-based nutrient supplement
UCT	Unconditional cash transfer
UNICEF	United Nations International Children's Emergency Fund
WASH	Water, Sanitation, and Hygiene
WAZ	Weight for age z-score
WHZ	Weight-for-height z-score

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Highlights

- This study identified 8 general pathways through which nutrition interventions lead to changes in diet and nutrition outcomes in low- and middle-income countries (LMICs) affected by shocks, conflicts, and crises (SCCs).
- Intervention pathways focused on food consumption, consumer awareness and behaviour change and on supporting systems, such as supplementation, enhancing maternal capacity and child feeding with support from health and childcare systems, showed positive results on improving nutrition outcomes (increased birthweight and height, reductions in moderate and severe acute malnutrition, mortality, anaemia, wasting, stunting, and underweight, as well as increased height-for-age and weight-for-age z scores).
- Pathways focused on interventions aiming to increase food accessibility and in food production and supply chains through cash transfers, food aid, food vouchers, and income from agriculture or own food production, demonstrated improvements in dietary outcomes (improved child feeding, dietary quantity, quality, and diversity).
- In contrast, pathways focused on interventions involving women's participation in agriculture and broader agri-food policies showed weaker and mixed effects on both dietary and nutrition outcomes.

Executive Summary

Background: The fragility of food systems in contexts of shocks, conflicts, and crises (SCC) can lead to disrupted food supply and increased food prices, affecting food environments, dietary habits, livelihoods and increasing food insecurity and malnutrition. The current literature is sparse in relation to the association between SCC, particularly conflict, and malnutrition. Although previous studies have explored links between nutrition-related interventions, food supply, prices and nutrition outcomes, there is limited research on the impact of these interventions within SCC contexts, especially during the recovery periods. Consequently, significant questions persist regarding the effectiveness of nutrition interventions in mitigating the adverse effects of SCC on dietary patterns and malnutrition in low- and middle-income countries (LMICs), and whether these interventions work through food system components such as food supply and food environments.

Objective: This research study aims to investigate general impact pathways of nutrition interventions conducted in contexts of SCC on dietary patterns and malnutrition in all its forms in LMICs. The study considers these effects from the perspectives of both the food environment and the broader food system.

Methods: To answer the research questions, we conducted a systematic overview of literature reviews by searching three databases (PubMed, Embase, and Cochrane), from inception up until 14 January 2024 with no language restriction. The search strategy followed the "Population, Intervention, Comparison, and Outcome" (PICO) framework. The population of interest included low- and middle-income countries, with the intervention focusing on both nutrition-specific and nutrition-sensitive approaches, encompassing various strategies such as food and micronutrient supplementation and social protection programmes. For outcomes, the primary focus was on malnutrition and dietary pattern shifts, with search terms covering related concepts such as undernutrition, nutritional status, and dietary quality. Additionally, terms related to food system components (e.g., food supply chain) and SCC (e.g., natural disasters and conflicts) were included. To ensure the quality and relevance of the included studies, the review was limited to previously published systematic reviews and studies involving women of reproductive age and/or children. The retrieved records from the searches were deduplicated and independently screened by two reviewers, first by title and abstract, and then by full text for eligibility. Relevant information was then extracted from the included articles, including study characteristics, interventions, and their impacts on investigated outcomes and food system components.

From 1130 deduplicated records identified from the three databases, 16 relevant reviews examining the impacts of nutrition interventions implemented within SCC context on dietary and nutrition outcomes in LMICs were included. The reviews were published between 2015 and 2024, including studies conducted in 51 countries/regions, most commonly in Africa and Asia. Conflict is the most common SCC context in these studies, followed by natural disaster.

Framework for impact pathways analysis

To map the impact pathways from nutrition interventions to dietary/malnutrition outcomes, this study adopts the food system framework from the FAO's "The State of Food Security and Nutrition in the World 2021[1] and 2022[2]". This comprehensive framework outlines the **intricate interactions and components within the food system**, which includes food supply chains, the food environment, consumer behaviour, diets, as well as nutrition and health outcomes. It also considers that the food system is **interconnected with other systems,** namely environmental (which include ecosystems that provide resources for food production), social protection, childcare, health and transportation and energy systems.

The framework proposed for analysis in this study illustrates food-systems' embedded actions to enhance nutrition outcomes in contexts of SCC, based on published evidence. Interventions were grouped based on the

components of the food system where they operate (entry points) and on the outcomes targeted by these interventions and were also classified according to the type of evidence of measured results.

The assessed interventions focused on:

I) Dietary intake (D-intake; foods and nutrients supplementation)
II) Food environment: a) Food accessibility (F-accessibility; conditional/unconditional cash and food transfer and voucher, agricultural employment for household income) and b) Other dimension of food environment (F-other; women's employment in agricultural activities)
III) Consumer awareness and behaviour (C-awareness and C-behaviour; nutrition education and women's empowerment)
IV) Supporting systems: a) Health system (S-health; health education, [referral] for medical treatment, training courses on acute malnutrition management); b) Childcare system (S-care; training health workers for maternal counselling for childcare and nutrition counselling or sessions such as feeding optimisation and cooking demonstration, enhancing community-based nutrition and nutrition education), c) Policies supporting food system (S-policy; food price volatility and regulation, and trade liberalisation), and d) social protection system (S-social; postwar social assistance programmes)
V) Food supply chains: a) Food production (F-production; homestead food production, crop- and bio-diversification, improving irrigation system, livestock ownerships and dairy production, and climate-smart agriculture) and b) Food waste and loss management (F-waste; reducing post-harvest losses and food waste)

The outcomes targeted by the interventions were subdivided into:

Dietary outcomes: dietary quantity (D-quantity; increased meal frequency and food consumption), dietary quality (D-quality; increased intakes of micronutrients and eggs, animal protein, beans, fruits, and vegetables), dietary diversity (D-diversity; increased intake of more types of food groups), and child feeding (D-child feeding; increased [exclusive] breastfeeding initiation, duration, and frequency).

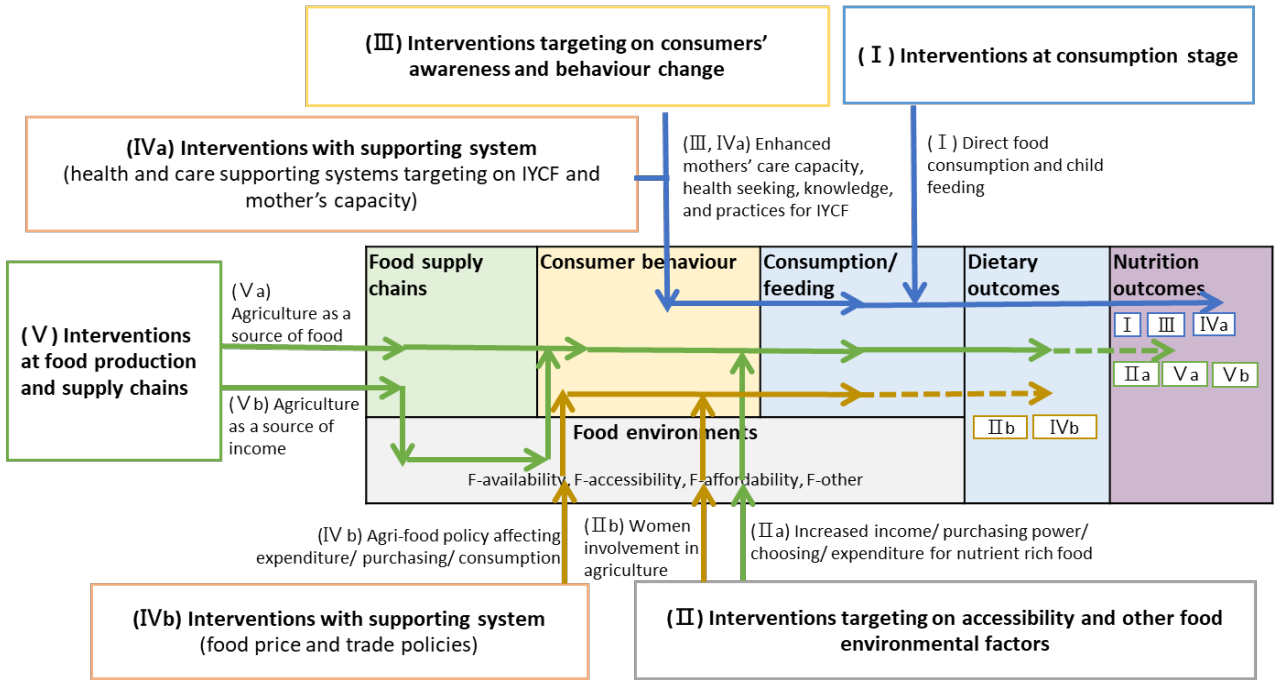
Nutrition outcomes: anthropometric measurements (N-anthropometry; including weight, height, weight-for-age (WAZ), height-for-age (HAZ) and their corresponding binary variables such as stunting and wasting), acute malnutrition (N-acute malnutrition; moderate/severe/global acute malnutrition), nutritional status (N-status; anaemia and iron deficiency), and mortality (N-mortality; lower mortality rate).

Results: Data for mapping impact pathways were derived from 87 relevant studies across 13 reviews and 71 mentioned interventions from 3 structurally distinct reviews, identifying 8 general intervention impact pathways leading to dietary and nutrition outcomes:

Pathway 1: Interventions at the consumption stage through direct food consumption and child feeding. (I)
Pathway 2: Interventions targeting consumer awareness and behaviour change through enhanced maternal care capacity, and health-seeking knowledge and practices for infant and young child feeding (IYCF). (III)
Pathway 3: Interventions with supporting systems (health and childcare systems) targeting IYCF and maternal capacity. (IVa)
Pathway 4: Interventions affecting accessibility by increasing income, purchasing power, and expenditure on nutrient-rich food. (IIa)
Pathway 5: Interventions in food production and supply chains utilising agriculture as a source of food. (Va)
Pathway 6: Interventions in food production and supply chains leveraging agriculture as a source of income. (Vb)
Pathway 7: Interventions affecting food environments through the involvement of women in agriculture. (IIb)
Pathway 8: Interventions with supporting systems (agri-food policy) affecting food purchasing, expenditure, and consumption. (IVb)

Pathways 1 to 3, which focus on supplementations, enhancing maternal capacity and child feeding with support from health and childcare systems, show strong evidence of improving nutrition outcomes (increased birthweight and height, reductions in moderate and severe acute malnutrition, mortality, anaemia, wasting, stunting, and underweight, as well as increased height-for-age and weight-for-age z scores). Pathways 4 and 6, which increase food accessibility through cash transfers, food aid, food vouchers, and income from agriculture or own food production, demonstrate promising improvements in dietary outcomes (improved child feeding, dietary quantity, quality, and diversity). In contrast, pathways 7 to 8, involving women's participation in agriculture and broader agri-food policies, have weaker and mixed impacts on direct consumption and dietary and nutrition outcomes (Summary figure).

Summary figure. General pathways from interventions to dietary and nutrition outcomes through food system



Blue arrow: interventions improved both dietary and nutrition outcomes; Green arrow: interventions improved mainly dietary outcomes; Brown arrow: interventions had mixed impacts on dietary outcomes; Dashed arrow: weak or mixed impacts on dietary/nutrition outcomes
IYCF: infant and young child feeding

Conclusion: This systematic review expands on the knowledge about nutrition interventions within LMICs in mitigating the adverse impacts of SCC on dietary patterns and malnutrition. Interventions targeting dietary intake, consumer awareness, and health or childcare systems showed potential to improv nutrition through enhanced consumption and behaviour changes. Interventions focused on agricultural food production and economic accessibility showed potential to improve dietary, and to a lesser extent nutrition outcome, by increasing own sources of food, income and purchasing power. Interventions involving women in agriculture and broader agri-food policies showed mixed results.

Overall, the findings underscore the importance of a multifaceted, evidence-based approach to tackle the nutrition challenges in LMICs facing SCC settings. The findings stress the need for comprehensive strategies integrating both nutrition-specific and nutrition-sensitive interventions to address malnutrition effectively and promote food security for vulnerable populations. Some challenges remain, namely the need for a deep understanding of these impact pathways, due to evidence gaps related to the low quality of the few available studies. Future research should prioritise rigorous methods and comprehensive impact evaluations.

Introduction

1.1 Background and context:

In recent years, high morbidity and mortality rates attributed to malnutrition in the context of shocks, conflicts, and crises (SCC) have drawn significant attention as pressing public health concerns. Factors such as pre-existing malnutrition, food insecurity, living conditions in shelters, inadequate breastfeeding practices, sociocultural influences, and organisational and administrative hurdles influence negatively the nutritional status of populations during disasters, particularly affecting children[3].

The world is currently grappling with a spectrum of SCC, impacting food systems[4,5] and leading to shifts in food supply, volatile prices, and increased risk of inadequate dietary patterns and malnutrition[6,7]. Historical events like the 2007-2008 food crisis[8], as well as more recent occurrences such as the Coronavirus disease 2019 (COVID-19)[9] pandemic and the ongoing Russia-Ukraine conflict[10], highlight the cascading effects of such situations on food systems, potentially exacerbating the risk of malnutrition. For example, Ukraine, as the world's fourth-largest exporter and a major cereal producer, is facing significant disruptions in agricultural production and exports due to the current conflict, impacting global food supply and prices. Over 95% of Ukraine's wheat exports typically go to countries in Africa or Asia. A study based on simulation suggests that the conflict could lead to 67.3 million new cases of undernutrition and extreme national food insecurity for 316.7 million people, with around 95% of the affected population hailing from developing countries[11].

Despite an existing body of literature connecting extreme climate events to child malnutrition[12], formal investigations and analyses of relationships with SCC, especially conflict-induced wasting, are limited. Moreover, studies on the effects of conflict on food security and public health have not translated into interventions. There is also a scarcity of literature on interventions during the SCC recovery period. Thus, there is a critical knowledge gap concerning the potential of nutrition interventions to mitigate the disruption in food supply and environments caused by SCCs, ultimately addressing malnutrition.

It has been suggested that increases in food price and trade disruptions affecting food, fertiliser, and fuel present a significant risk of aggravating the global prevalence of malnutrition, particularly among women and children, through three main ways[13]: 1) rising prices and decreased food accessibility directly affect dietary quality, especially in low-income countries where populations spend a larger proportion of their household income on food; 2) elevated prices and trade interruptions may hinder access to vital humanitarian services, exacerbating malnutrition rates; 3) countries may divert funds from nutrition improvement initiatives to other priorities when facing SCC.

While many studies have explored the association between food availability/prices and nutritional status[14], there has been a dearth of research focusing specifically on the nuanced effects of fluctuations in food supply and prices within the context of SCC. The current study aims to investigate impact pathways of nutrition interventions conducted within SCC contexts, on dietary patterns and malnutrition in all its forms in LMICs, through a systematic literature review. The study considers these effects from the perspectives of both the food environment and the broader food system. The present research study stems from evidence needs prioritisation exercise conducted by the Nutrition Research Facility (NRF) through an online consultation process with decision-makers in Asia. Specifically, it aims at addressing a top-priority question for nutrition programming, which was formulated as: “How does changing food supply and food prices impact on dietary patterns and therefore on nutritional status (all forms of malnutrition) in children under-five and women of reproductive age?”. During the consultations, the question was outlined by the critical need to focus on SCC and recovery. A high interest in addressing this question to inform policies was expressed by countries that are persistently or recurrently suffering from SCC, namely Uzbekistan, the Philippines, Yemen and Bangladesh.

1.2 Contribution to the European Union Plan of Action on Nutrition:

Aligned with the European Union Plan of Action on Nutrition, this study contributes to the EU's commitment to advancing efforts for healthy and sustainable diets. The recent pledge of an additional EUR 2.5 billion for international assistance with a nutrition focus[15] reinforces the EU's strategy to decrease stunting in children under the age of five by at least 10%, aligning with the World Health Assembly's target by 2025. Acknowledging the adverse effects of global SCC on food systems and global nutrition, particularly during the COVID-19 pandemic and the Russia-Ukraine conflict, this study investigates the impact pathways of interventions in SCC-affected populations, primarily in low- and middle-income countries (LMICs), where the impacts are most pronounced.

1.3 Research question(s):

The primary research question guiding this study is: Can nutrition-related interventions effectively reduce the adverse effects of SCC on dietary patterns and malnutrition in LMICs? If so, what are the impact pathways of these interventions?

1.4 Specific objectives:

The study has two specific objectives:

1. Identify nutrition-specific and nutrition-sensitive interventions mitigating the effects of SCC on dietary and nutrition outcomes in LMICs.
2. Summarise the available evidence on the impact pathways of these interventions on dietary and nutrition outcomes in the context of SCC.

1.5 Intended audience and use of the report:

The primary audience for this research study includes decision-makers seeking evidence regarding the impact pathways linking nutrition interventions implemented in SCC context to malnutrition, particularly through changes in food supply and food prices. This report corresponds to the first study component, a systematic literature review aimed at synthesising existing evidence on these pathways. Although the overall study initially prioritised Asian contexts, the scope of the systematic review was broadened to encompass evidence from LMICs more broadly. This expansion was necessary to ensure a more robust evidence base, given on the limited number of literature reviews focusing specifically on SCC contexts in Asia.

As a result, the beneficiaries of this study include decision-makers in LMICs, including but not limited to Asia. In addition, the study's findings are expected to indirectly benefit populations at risk of malnutrition in SCC contexts, since the evidence from this review can contribute to support the design of more effective nutrition strategies and interventions.

Methodology

This report describes the first component of the study, "Impact Pathways from Shocks, Conflicts, and Crises to Malnutrition through Changing Food Supply and Food Prices," spearheaded by the NRF team. The first component consists of a systematic literature review, that will be followed by a second component consisting of a secondary analysis involving participatory methodologies with multidisciplinary experts to validate the general impact pathway framework. The two-phase approach ensures a comprehensive exploration of the intricate connections between SCC, and malnutrition.

Overview of the contextualised research question:

While published research has examined the associations between nutrition-related interventions and nutrition outcomes through food supply and prices, there is a lack of focus in the context of SCC. This study thus investigates how nutrition interventions in SCC affect nutrition outcomes through food system components like food supply and prices, particularly among vulnerable groups such as women and young children.

To gather relevant data, we conducted a systematic review of systematic or scoping reviews of published studies[a] on the dietary and/or nutritional impacts of nutrition-related interventions in contexts of SCC, and analysed the findings based on the analytic framework detailed below. The approach of restricting the search to literature reviews may have the limitation of potentially missing some key studies or limiting the level of details retrieved, although it is not expected to have a great negative impact on the findings. To mitigate this, we supplemented our data extraction by incorporating relevant original studies cited in the included reviews. This allowed to capture additional details on food systems components that might not have been fully described in the reviews themselves.

2.1 Theoretical foundation:

2.1.1 Definitions

Shocks, Conflicts and Crises: Shocks, characterised by sudden and unexpected events like natural disasters and public health emergencies (e.g., pandemics)[16], have the potential to disrupt food supply and prices, influencing dietary patterns and malnutrition. Conflicts manifest as violent struggles or oppositions among different groups or factions, often resulting in population displacement, disruption of food supply chains, and alterations in dietary patterns. Examples of conflicts encompass international or civil wars and political upheavals[17]. Crises such as economic recessions and climate change are characterised by profound challenges and can be precipitated by shocks or conflicts[18].

These events often result in substantial disruptions in food supply chains and fluctuations in prices. SCC are interconnected[17], with one event potentially causing another, and each amplifying the impact of the other. For example, a natural disaster may lead to resource scarcity, triggering conflict, while conflict can result in economic instability. Prolonged conflict and shock can contribute to crises like famine and economic recession. Moreover, regions grappling with crises may exhibit increased vulnerability in responding to various shocks, with food insecurity exacerbating other factors that can ultimately lead to conflict[17].

Nutrition interventions: Nutrition interventions to address malnutrition can be divided into nutrition-specific and nutrition-sensitive interventions[19,20]. Nutrition-specific interventions directly target the immediate causes

[a] A limitation of our methodology lies in our emphasis on systematic reviews rather than original studies due to feasibility issues identified during the desk background search. Despite a clear evidence gap regarding impact pathways linking nutrition interventions in the context of SCC to malnutrition, a well-structured systematic search in scientific databases might result in a burdensome task from a timewise perspective. To manage this, we opted to restrict our inclusion criteria to published systematic reviews.

of malnutrition, including strategies like micronutrient supplementation, food fortification, feeding programmes, treatment of severe acute malnutrition, breastfeeding promotion, and support for Infant and Young Child Feeding (IYCF). In contrast, nutrition-sensitive interventions focus on addressing the underlying determinants of malnutrition, such as poverty, food insecurity, and limited access to essential resources. Nutrition-sensitive strategies include cash transfers, social safety nets, enhancement of agricultural practices, income generation programmes, women's empowerment initiatives, educational interventions, and behaviour change communication efforts. These approaches aim to create sustainable changes in socio-economic and environmental factors contributing to malnutrition.

2.1.2 Proposed framework for analysis of impact pathways

To map impact pathways from nutrition interventions to dietary and nutrition outcomes, the study adopts the food system framework depicted in recent Food and Agriculture Organization of the United Nations (FAO) publications: The State of Food Security and Nutrition in the World 2021[1] and 2022[2]. This framework provides a comprehensive view of the intricate interactions and components within the food system. **Table 1** presents the framework proposed in this study for analysing impact pathways of nutrition intervention in the context of SCC. The core food system components considered in the proposed framework for analysis include food supply chains, the food environment, consumer behaviour, diets and nutrition and health outcomes.

Table 1. The proposed framework for analysis, including the key components and subcomponents within each component (adapted from the HLPE/FAO 2021 and FAO 2022 food system framework).

<table>
<tr><td>Drivers</td><td colspan="4">Shocks, conflicts, and crisis (SCC)</td><td>Impact</td></tr>
<tr><td rowspan="2">Agri-food system</td><td rowspan="2">Other systems supporting food systems</td><td rowspan="2">Food supply chains</td><td rowspan="2">Consumer behaviour</td><td>Diets</td><td rowspan="2">Nutrition and health</td></tr>
<tr><td>Consumption Feeding</td><td>Dietary outcome</td></tr>
<tr><td rowspan="3">Intervention and outcome description and classification</td><td>S-social
Social protection system
S-health
Health system
S-others
Environmental
Transportation system
Energy systems
Other systems
S-care
Childcare
S-policy
Policy, governance, and political economy; food and agricultural policy support</td><td>F-production
Food and agricultural production systems
F-processing
Packaging and processing
F-market
Storage and distribution
Wholesale, retail, and marketing
International trade
F-waste
Food waste and loss management</td><td>C-behaviour
Choosing when and what food acquire, prepare, cook, store, and eat.
C-awareness
Information and awareness of nutrition and health and impacts of choices</td><td>D-intake
Intake
Feeding</td><td>D- quality
D- quantity
D-diversity
D-child feeding</td><td>N-status
N-anthropometry
N-acute malnutrition
N-mortality

Others: social, economic, environments, ecosystems</td></tr>
<tr><td></td><td colspan="3">Food environment
F-availability: Factors addressing availability
F-accessibility: Physical/social/ economic access to food
F-affordability: Factors addressing purchasing/ expenditure and prices for nutrient-rich food
F-utilisation: Utilisation and food quality and safety</td><td colspan="2"></td></tr>
</table>

1) Characterisation of food system components

Food supply chains encompass all stages from food production to distribution, including agricultural production, storage, distribution, packaging, processing, wholesale, retail, marketing, international trade, and food waste and loss management. Each stage involves multiple actors and processes that influence the system's overall efficiency and sustainability. **Consumer behaviour** focuses on how individuals choose, acquire, prepare, cook, store, and consume food. It is influenced by information and awareness about nutrition, health, and the impacts of dietary choices. **Diets** involves the quality, quantity, diversity, safety, and adequacy of diets, which determine the dietary intake of individuals. **Nutrition and health** outcomes refer to the direct impacts of dietary intake on nutrition status and health, which are critical in determining food security and the overall well-being of populations.

The **food environment** refers to the physical, economic, political, and socio-cultural contexts in which consumers interact with the food system to make decisions about acquiring, preparing, and consuming food[21]. This context could be at multiple levels—individual, local, and regional/global—and encompasses various dimensions including availability and physical access (proximity), economic access (affordability), promotion/advertising and information, as well as food quality and safety[21]. These elements align with the three pillars of food security: availability, accessibility (physical, economic, and social), and utilisation. In this study, the factors influencing food environment are categorised according to food security pillars: Food availability addresses the physical presence of food; factors like germplasm and production technology targeting abiotic and biotic stresses enhance food availability. Food accessibility focuses on the economic and physical access to food, considering factors like food prices, household income, and infrastructure. Food affordability is part of food accessibility and addresses the economic aspect, focusing on the purchasing power of households to acquire nutrient-rich foods. Higher household incomes and government interventions, such as food subsidies or assistance programmes, can improve food affordability. Food utilisation involves the proper use of food based on nutritional knowledge, dietary preferences, and food safety. Education and awareness about nutrition and healthy eating practices, along with effective food safety practices, are critical for optimal food utilisation.

The food system requires the support of other interconnected systems (**supporting systems**) to function effectively. Environmental systems include ecosystems that provide the necessary resources for food production, such as water, soil, and biodiversity. Social protection systems are designed to support vulnerable populations by ensuring access to food and other necessities during times of crisis. Childcare systems support the nutritional and health needs of children, ensuring proper feeding, growth, and development. Health systems contribute to public health by providing healthcare services and medical treatments. Transportation and energy systems are essential for the efficient functioning of food supply chains, affecting the transportation and processing of food.

2) Classification of interventions

In the proposed framework for analysis, interventions were structured based on the components of the food system where they operate:

(1) Food supply chains: F-production, F-processing, F-market, F-waste
Consumer behaviour: C-behaviour and C-awareness
Diets: D-intake
(2) Food environments: F-availability, F-accessibility, F-affordability and F-utilisation and F-other
(3) Supporting system: S-social, S-health, S-care, S-policy and S-others

For example, “F-production” interventions target the food and agriculture production stage of the “Food Supply Chain” component of the food system. These interventions include homestead food production, integrated

vegetable and fish production, and crop diversification programmes. "F-accessibility" interventions focus on the factors influencing physical, economic, or social access to food within the "Food Environment" component of the food system. These interventions include unconditional cash transfers, food vouchers, and agricultural employment programmes that support household income. "C-awareness" interventions aim to enhance consumers' awareness and knowledge about diets, nutrition, and the impact of food choices. These interventions include education programmes on Infant and Young Child Feeding (IYCF) and nutrition. "D-intake" interventions focus on the consumption and feeding stage of the "Diets" component within the food system. Examples of these interventions include micronutrient supplementation, food fortification, food distribution/aid, and child/school feeding programmes. "S-health" interventions provide health counselling, primary healthcare, and medical treatments to mothers and consumers to support the health of themselves and their children. These interventions are grouped under the "Other Systems Supporting the Food System" (see **Table 1**).
The interventions were also structured according to the outcomes targeted by these interventions:

Dietary outcomes were classified into four types of evidence: D-quantity (e.g., increased meal frequency), D-quality (e.g., increased vegetable and fish intakes), D-diversity (e.g., increased dietary diversity) and D-child feeding (e.g., increased frequency of exclusive breastfeeding).

Nutrition outcomes were similarly classified into four types of evidence: N-malnutrition status (e.g., reduced cases of anaemia), N-anthropometry (e.g., reduced stunting rate), N-acute malnutrition (e.g., severe malnutrition rates), N-mortality (e.g., child mortality rates) (see **Table 1**).

Ultimately, the interventions were classified according to the type of evidence of measured results. While some reviews provided summary estimates solely for impact measures related to dietary/nutrition outcomes, offering limited empirical evidence for the associated pathways, we chose to incorporate such reviews into our analysis. In doing so, we explicitly acknowledged the absence of empirical data or emphasised the theoretical nature of the proposed pathways, if applicable. We also endeavoured to extract additional data on food system components from the original studies included in the review.

3) Mapping impact pathways

The impact pathway for each study was mapped from the food system component where the intervention was primarily implemented, following the food system framework toward the measured dietary and nutrition outcomes. A general impact pathway was then mapped using the grouped studies with similar types of interventions, following the food system framework toward the major outcomes measured.

2.2 Systematic literature review

2.2.1 Search term generation

The search strategy was guided by the "Population, Intervention, Comparison, and Outcome" (PICO) framework[22], which breaks down a research question into searchable components. The detailed search terms have been described in detail previously and also attached in the Annex (Table S1A-S1C). The Population of interest is low- and middle-income countries, and search terms included synonyms of these terms and list of specific countries defined by World Bank[23]. The Intervention of interest is nutrition-specific and nutrition-sensitive interventions, including micronutrient supplementation, food fortification, feeding programmes, treatment of severe acute malnutrition, promotion of breastfeeding, support for IYCF and agriculture, health, social protection, early child development, and education. The broad terms "nutrition-specific" and "nutrition-sensitive" interventions were also included to improve comprehensiveness of the search. Because the

Comparison involved a control group without the intervention, no additional search terms are included, as these would have been covered by the "Intervention" search terms. For Outcomes, the primary focus is on malnutrition and shifts in dietary patterns. This encompasses various terms such as malnutrition, undernutrition, dietary quality, nutrients, micronutrient deficiency, and nutritional status, including stunting, wasting, height-for-age, and weight-for-age, overweight and obesity. To address the research question, we also included search terms related to 1) food system components including food supply chain, food environment, and consumer behaviour and 2) context of SCC such as natural disaster, war, pandemic, and recession. Two further restrictions were added, according to feasibility criteria: 1) only previously published systematic reviews were addressed; 2) only studies involving women of reproductive age and/or children were considered to align with priority population groups identified by the decision-makers.

The specific inclusion and exclusion criteria were as follows:

Inclusion criteria

- Only systematic reviews of studies assessing effectiveness or impact or pathway of nutrition interventions on malnutrition or dietary changes in the context of SCC and post-SCC in LMICs were included.
- Only studies involving women of reproductive age and/or children were included.

Exclusion criteria

- Editorial, comment, letter/reply to the editor, grey literature, conference abstract
- Studies focusing on upper-middle-income or high-income countries
- Other studies with irrelevant context or topics

2.2.2 Database searches, study screening and selection

Using the search terms, three databases, PubMed, Embase, and Cochrane were searched from their inception to 14 Jan 2024. Two reviewers independently conducted a two-stage screening process: initially screening titles and abstracts, followed by a review of full-text articles. If disagreements arose and consensus could not be reached, a third reviewer served as an arbitrator to facilitate resolution during the negotiation process.

We performed forward and backward citation tracing for the included articles by examining both the reference lists of the included articles and identifying studies that cited the included articles, respectively. Additional manual searches were conducted to supplement the existing evidence base.

2.2.3 Data extraction

We extracted information regarding the countries where the original studies were conducted, the range of years of publication of the original studies, the total number of participants included in the review, the types of SCC, the types of nutrition interventions utilised, objectives of the intervention, the impacts on dietary and nutrition outcomes, and impacts on food supply and food environment pathways. The data extraction was conducted by two reviewers who cross-checked each other's work for 30% of the extractions. The data extraction was also verified by a third reviewer for accuracy. Any discrepancies were resolved by discussion.

2.2.4 Data synthesis and analysis

We anticipated encountering diverse study designs and a high degree of heterogeneity in intervention and outcome measurements, which would pose challenges for statistically pooling data across different systematic reviews. Consequently, we did not plan to conduct meta-analysis. Instead, our primary strategy revolved around employing narrative summaries to synthesise the available evidence. This narrative approach involved extracting the effects of interventions on food systems and dietary and nutrition outcome/impact measures from the reviewed studies, including the direction and number of studies reporting statistical significance.

2.2.4.1 Cross-cutting issues

The study addresses the following cross-cutting issues to ensure a comprehensive understanding of its impact. This includes a focus on gender, recognising the differential impacts of changing food supply and prices on women of reproductive age. For climate action and sustainable development, our investigation includes SCC context of climate change and natural disasters such as drought. By investigating the impact pathways of interventions on nutrition and dietary patterns, our investigation is well-aligned with Sustainable Development Goal 2: Zero hunger and Goal 3: Good health and well-being. The study also adopts a rights-based approach, acknowledging the human right to health, encompassing "an adequate supply of food and proper nutrition"[24]. Furthermore, the research aligns with the principle of "leave no-one behind", concentrating on vulnerable populations such as children under-five and women of reproductive age in LMICs amid SCC.

2.2.5 Risk of bias assessment

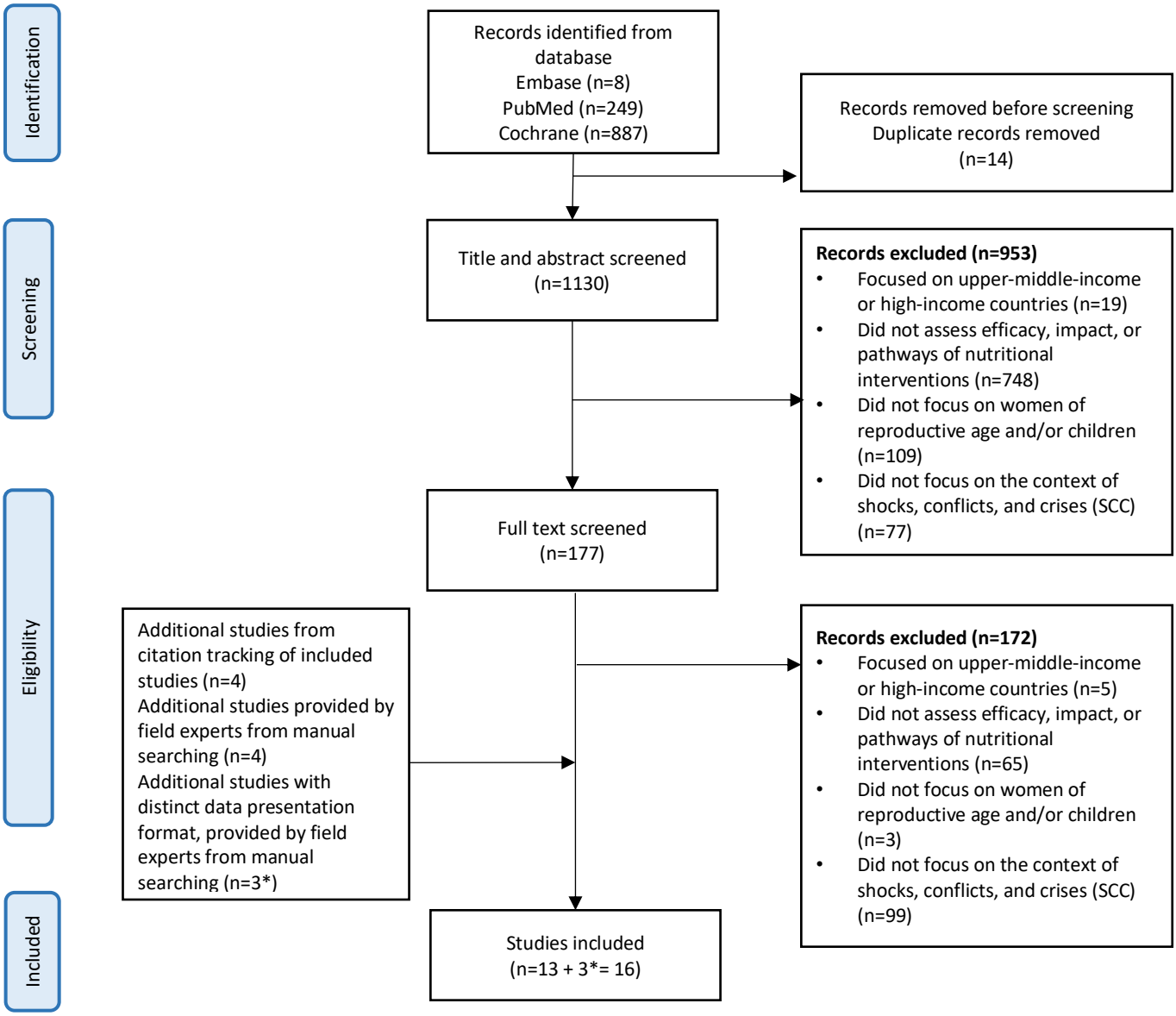
To assess the quality of the included systematic reviews, we employed AMSTAR 2 (A MeaSurement Tool to Assess Systematic Reviews 2)[25]. AMSTAR 2 is a widely utilised critical appraisal tool specifically designed for assessing systematic reviews that incorporate randomised or non-randomised studies of healthcare interventions, or both. Subsequently, we assigned ratings to the studies based on their quality, categorising them as high, moderate, low, or critically low.

Results

3.1 Characteristics of included publications

We identified 1144 records from the databases. After removing duplicates, 1130 hits remained and were screened by title and abstract and 177 were screened in full text and 172 were then excluded (**Figure 1**). Additional studies from citation tracking of the included studies (n=4) and the studies provided by field experts from manual searching (n=7) were added. In total, 16 articles were included in this review.

Figure 1. Flow diagram of included studies



*Three publications were analysed separately due to their distinct data presentation formats

Study characteristics, including the number of studies, participants, age range, SCC situation, target countries, and information on types of interventions, effects on food system components, measured dietary and nutrition outcomes and proposed pathways towards outcomes, were retrieved from each review articles. Additionally, relevant original studies within these reviews were examined as needed to gather more information on the impacts on diets, nutrition outcomes, and/or effects on food system components.

Due to different structure of the review articles, summary characteristics and study information from 13 review articles[26–38] and 87 relevant original studies within the 13 reviews are reported in **Annex Table S2A.** Further details, including study objectives, possible pathway (where available) and details of interventions described in the 13 reviews are provided in **Annex Table S2B**. The study characteristics and information for another 3 structurally distinct review articles and 71 interventions discussed within these reviews are presented in the **Annex Table S2C.** Additional text descriptions of these three reviews are presented in **Annex Text S1**.

The 3 structurally distinct review articles include one report on recommended interventions for climate change[39], as well as two reviews on agriculture-to-nutrition pathways in India[40] and Bangladesh[41], respectively. These three reviews were detailed separately because two of them already organised and discussed some of their included interventions based on a specific framework, while the other review focused on general recommended interventions rather than a systematic review of existing studies. Consequently, the structure, presentation, and level of detail that could be extracted from these reviews differed significantly from the other 13 reviews.

According to AMSTAR 2 appraisal, one review study among the 16 received a moderate quality rating, while the remaining review studies were rated as having low/critical low quality (**Annex Table S3**).

3.1.1 Target countries

Included studies in the 16 reviews were conducted in 51 countries/regions, mostly in Africa (n= 23) and Asia (n= 19): Afghanistan, Algeria, Bangladesh, Bhutan, Bosnia-Herzegovina, Burundi, Cameroon, Central African Republic, Chad, China, Democratic Republic of Congo (DRC), Ecuador, El Salvador, Ethiopia, Guinea Bissau, Haiti, India, Indonesia, Iran, Iraq, Jordan, Kenya, Kosovo, Lebanon, Liberia, Macedonia, Madagascar, Malawi, Mali, Mexico, Myanmar, Nepal, Nicaragua, Niger, Pakistan, Palestine, Philippines, Sierra Leone, Somalia, South Sudan, Sri Lanka, Sudan, Syria, Tanzania, Togo, Thailand, Uganda, Ukraine, Yemen, Zambia, Zimbabwe.

3.1.2 Study years and participants

The number of participants included in the 13 reviews ranged from 140 to 1136311 individuals. The review studies were published between 2015 to 2024, including original studies published between 1993 to 2022. Numbers of participants of the studies in the 3 structurally distinct reviews were not indicated.

3.1.3 SCC characteristics

The 87 relevant original studies in the 13 reviews covered a range of SCC context and humanitarian settings, including conflict (n= 38; 10 reviews), natural disaster (n= 12; 5 reviews), SCC-sensitive countries/non-specified (n= 18; 4 reviews), food crisis/seasonal hunger (n= 9; 3 reviews), economic crisis (n= 4; 2 reviews), and combination [n= 6: conflict + natural disaster (n= 3), conflict + economic crisis (n= 1), natural disaster + food crisis (n= 1), conflict +food crisis +economic crisis (n= 1); 6 reviews]).

Of the 3 reviews, one focused on recommended interventions for adapting to climate change, while the other two specifically reported on India and Bangladesh, both SCC-sensitive countries.

3.1.4 Intervention characteristics

The details and descriptions of the classified interventions in the included studies are listed in **Table 2**.

A range of interventions in relevant original studies were studied in relation to dietary or nutrition outcomes (**Table 2**), including those targeting:

I) Dietary intake (D-intake; foods and nutrients supplementation)

II) Food environment: a) Food accessibility (F-accessibility; conditional/unconditional cash and food transfer and voucher, agricultural employment for household income) and b) Other dimensions of food environment (F-other; women's employment in agricultural activities)

lll) Consumer awareness and behaviour (C-awareness and C-behaviour; nutrition education and women's empowerment)

lV) Supporting system: a) Health system (S-health; health education, [referral] for medical treatment , training courses on acute malnutrition management); b) Childcare system (S-care; training health workers for maternal counselling for childcare and nutrition counselling or sessions such as feeding optimisation and cooking demonstration, enhancing community-based nutrition and nutrition education), c) Policy supporting the food system (S-policy; food price volatility and regulation, and trade liberalisation), and d) social protection system (S-social; postwar social assistance programmes)

V) Food supply chains: a) Food production (F-production; homestead food production, crop- and bio-diversification, improving irrigation system, livestock ownerships and dairy production, and climate-smart agriculture) and b) Food waste and loss management (F-waste; reducing post-harvest losses and food waste)

In some included reviews, certain interventions were included for purposes unrelated to assessing dietary or nutrition outcomes (e.g., measuring intervention coverage or exploring outcomes beyond the scope of this study). These details are presented in **Annex Table S4**.

Table 2. Type of interventions classified based on the adopted food system framework

Components	Key stages, systems, and components	Type of interventions	Interventions in the studies
Food supply chains (F)	• Food and agricultural production systems	F-production	Technology or programme aiming at enhanced seed quality, yield, produce quality and cultural and postharvest management • Homestead food production[41] • Ricefield-based fish seed production[41] • Vegetable production program[41] • Crop production & diversification[41] • Large-scale, crop-diversification project[41] • Integrate fish and vegetable production into aquaculture systems[41] • Backyard poultry raising[41] • Irrigation and farm size[40] • Cow and buffalo production & ownership[40] • Dairy production and joining cooperatives[40] • Production of the improved small ruminant breeds[39] • Biofortification programmes[39] • Climate-smart agriculture[39] • Farm diversity[39] • Seed and voucher fairs[39] • Solar-powered drip irrigation technology[39] • Livestock ownership[39]
	• Packaging and processing	F-processing	Processing technology or programme aimed at enhancing shelf life, quality, and distribution • No interventions identified
	• Storage and distribution • Wholesale, retail, and marketing • International trade	F-market	Technology or programme that enhancing storage capacity, wider and longer distribution, improving marketing, and trading for targeted supply chains • No interventions identified
	• Food waste and loss management	F-waste	Technology or programme aiming at reducing food waste and loss; food bank program; composition program • Reducing post-harvest losses and food waste[39] • Targeting women in campaigns to reduce food loss and waste[39]

Table 2. Type of interventions classified based on the adopted food system framework (continued)

Components	Key stages, systems, and components	Type of interventions	Interventions in the studies
Consumer behaviour (C)	• Choosing when and what food acquire, prepare, cook, store, and eat.	C-behaviour	Programmes aiming at changing consumers' behaviours toward choosing/ preparing/ consuming nutrient-rich or healthy food ingredients or diets • Women empowerment[40]
	• Information and awareness of nutrition and health and impacts of choices	C-awareness	Nutrition/health education and/or courses including infant and young child feeding provided to household women, care givers and targeted consumers • Maternal and infant and young child feeding nutrition education[42–53]
Diets (D)	• Quantity, quality, diversity, safety, adequacy	D-intake	Food and micronutrient supplementation, fortification, food distribution/aids, child feeding/ school feeding programmes • Formulated supplementary foods[46,54–63] • Micronutrient supplementation[45,58,60,61,64–70] • Corn Soy Blend Plus[68,71–75] • Food ration[76–78] • Ready-to-use supplementary/ therapeutic food[48,70–74,79–82]
Food environment dimensions (F)	Factors addressing food availability	F-availability	Programmes that support local production, farmers' markets, and crop diversifications • No intervention identified
	Factors addressing food accessibility	F-accessibility	Programmes aiming at enhancing the economic and physical accesses to food, targeted/ untargeted cash transfer, food vouchers, income generation program, agricultural employment, opportunity in participating in food supply chain • Unconditional/conditional cash transfer[39,59,83–96,96–99] • Food voucher[91,92,94,97,100] • Food transfer[91,94,96,101] • Agricultural employment for household income[41]
	Factors addressing food affordability	F-affordability	Increasing purchasing power for healthy foods • No intervention identified
	Factors addressing food utilisation and others	Other dimensions of food environment (F-utilisation/ F-other)	Utilisation: Programmes aimed at enhancing food safety or reducing exposure to health risks, mass media nutritional promotion, promotion campaigns for healthy diets Utilisation: • No intervention identified Others: • Mothers serving as agricultural workers, pluckers in tea plantations[41] • Mothers engaged in agricultural activities[41] • Farmer training and dissemination of low-cost aquaculture technologies[41]
Supporting systems (S)	• Social protection system	S-social	Providing social safety net for vulnerable populations • Postwar social assistance programmes[102] • Productive Safety Net[96]
	• Health system	S-health	Providing health counselling services; primary healthcare; medical treatments; health workers trainings; water, sanitation and hygiene program • Improve sanitation/hygiene practies[54,63,103] • Health education[68,70] • Refer for treatment[48,55,70,74] • Medical treatment[61,64,82] • Maternal education and counselling[81] • Hold training courses on acute malnutrition management for doctors, nurses, medical students, and health workers[74,81,104]
	• Childcare system	S-care	Community-based nutrition/ childcare centres offering nutrition and care support, promoting, and providing child health

Table 2. Type of interventions classified based on the adopted food system framework (continued)

Components	Key stages, systems, and components	Type of interventions	Interventions in the studies
			programmes focusing breastfeeding and complementary feeding practices • Implement nutrition-specific supervision[62,105] • Standard growth monitoring[49,62] • Nutrition education[45–47,51,62,69] • Provide counselling or sessions (feeding optimisation, hygiene instruction, and a cooking demonstration)[46,48,52,70,75,95,100] • Promote exclusive breastfeeding[106–111] • Enhance community-based nutrition[46,50,64,112–115] • Training health workers on mother counselling for childcare[116] • Provide tents to offer a safe place for mothers to breastfeed[117]
	• Policy supporting food system	S-policy	Implementing policy that supporting sustainable agricultural practices and food security; regulations to limit the marketing of unhealthy foods to children; policy that promoting local food production • Rice price regulations[40,41] • Food price volatility[41] • Trade liberalisation[41] • Rice or wheat prices regulation[40] • Coarse grain prices regulation[40]
	• Environmental system • Transportation system • Energy system • Governance, political economy and others	S-others	• Postwar economic assistance programmes (especially land reform)[102]

3.1.5 Outcome measurements

Details on the classification of dietary and nutrition outcomes, along with the measured outcomes in the studies, are provided in **Table 3**. The outcomes measured in the included studies included a range of dietary outcomes including dietary quantity (D-quantity; increased meal frequency and food consumption), dietary quality (D-quality; increased intakes of micronutrients and eggs, animal protein, beans, fruits, and vegetables), dietary diversity (D-diversity; increased intake of more types of food groups), and child feeding (D-child feeding; increased (exclusive) breastfeeding initiation, duration, and frequency). Nutrition outcomes included anthropometric measurements (N-anthropometry; including weight, height, weight-for-age (WAZ), height-for-age (HAZ) and their corresponding binary variables such as stunting and wasting), acute malnutrition (N-acute malnutrition; moderate/severe/global acute malnutrition), malnutritional status (N-malnutrition status; anaemia and iron deficiency), and mortality (N-mortality; lower mortality rate).

Table 3. Type of dietary and nutrition outcomes classified based on evidence measured

Components	Type of evidence measured	Type of outcomes classified	Outcomes measured in the studies
Dietary outcomes	• Quantity	D-quantity	Increased consumption of food; enhanced food security • Increased meal frequency[42,84,90–93,118] • Increased food and nutrient consumption[54,63,88,94,96,100,101,119] • Increased food security[85,88,93,99]
	• Quality, safety, adequacy	D-quality	Increased intake of micronutrients, nutrient-rich food, fruits and vegetables, animal source food • Increased intake of beans, fruits, green leafy vegetables, egg, animal protein and peanut/seed butters and micronutrients[42,54,63,87,89,90,93,94,96,116,119]
	• Diversity	D-diversity	Increased intake of more types of food groups, increased dietary diversity score • Dietary diversity[42,83,84,86–89,91,93,94,96,100,101,115,118,119]
	• Child feeding	D-child feeding	Increased rates of exclusive breastfeeding in the first 6 months; improved complementary feeding practices • Feeding duration[82] • Initiation of breastfeeding within 1 hour of birth.[64,95] • Breastfeeding frequency[43,63,107,116,120] • Exclusive breastfeeding[95,108,110,113,114,117]
Nutrition/health outcomes	• Malnutrition status measured with biochemical indicators	N-malnutrition status	Reduced level or rates of micronutrient deficiencies - reduced iron-deficiency anaemia, vitamin A deficiency, zinc deficiency • Anaemia, iron deficiency, haemoglobin levels[43,46,57,60,62,65,66,73,119,121]
	• Growth and development measured with anthropometry indicators	N-anthropometry	Reduced child stunting and wasting, reduced prevalence of overweight and obesity • Height, weight[44,48,52,66,71,73,79,82,98,111,122] • Wasting, underweight, stunting, height-for-age z-score, weight-for-age z-score, weight-for-height z-score, mid-upper arm circumference[42,44–47,48–50,52,56,57,60,65–68,75,79,80,82,92,97,102,116,119,123–125] • Neonates' body weight, head circumference [77,78]
	• Acute malnutrition	N-acute malnutrition	Decreased cases of severe/ moderate acute malnutrition, improved recovery rates from acute malnutrition. • Moderate acute malnutrition[59,74,104,113,126] • Severe acute malnutrition[47,48,59,74,75,81,104,105,113,126] • Global acute malnutrition[47,51,55,61,69,70,74,76,79,82,90,92,127]
	• Mortality	N-mortality	Reduced maternal mortality, lower child mortality rate • Mortality[48,59,75,80,109,124,127]

3.2 Effects of nutrition-specific and -sensitive interventions

The information retrieved from the 87 original studies in the 13 reviews, and from the 71 discussed interventions in the 3 reviews, were organised to emphasise the pathway and evidence measured from interventions to dietary and nutritional outcomes through their effects on the food system, with the results presented in **Annex Tables S5 and S6**, respectively. Additionally, the same types of interventions from the 87 studies in **Annex Table S5** and 71 mentioned interventions in **Annex Table S6** were grouped and summarised in **Table 4 in the main text**, showing the accumulated number of studies for each intervention type.

Below, we provide a general overview of the impact of nutrition interventions on dietary and nutrition outcomes and food system components. **Sections 3.2.1 – 3.2.5** provide more specific and detailed descriptions according to the major types of interventions and the pathways from the intervention to the measured outcomes.

Impact on dietary and nutrition outcomes

Overall, from the 13 reviews, it was observed that nutrition interventions in SCC were associated with improved dietary and nutrition outcomes. Nutrition-specific interventions involving supplementary feeding, which directly target dietary intake, led to improvements in nutrition outcomes. Nutrition-sensitive interventions targeting food accessibility led to improvements in dietary outcomes, but evidence regarding their effectiveness in improving the nutritional status remains limited.

The 3 additional reviews mainly concern nutrition-sensitive interventions involving food production, food accessibility, food environment, and agri-food policy supports. Overall, interventions involving food production and food accessibility led to improvements in dietary outcomes and to a lesser extent nutrition outcome. Interventions involving other dimension of food environment (women's employment and engagement in agriculture) and agricultural policy resulted in mixed (both negative and positive) impacts on dietary and nutrition outcomes.

Effects on the food system components

Direct measurements of the effects of the intervention on the food system components are limited, with the focus primarily on food accessibility/affordability and consumer awareness/behaviours. When also considering theorised impact pathway, interventions targeting food accessibility affected dietary and nutrition outcomes through food environment dimensions including food affordability as well as consumer knowledge and behaviour. Interventions targeting consumer awareness and supporting health and care systems reported increased consumer awareness, with positive impacts on both dietary and nutrition outcomes. Nutrition-specific intervention targeting dietary intake predominantly act through food system via direct food and nutrient intakes and child feeding to improve diets and nutrition.

The 3 additional reviews primarily focus on interventions related to food production, food environment, and agri-food policy support. Two review studies[40,41], conducted in India and Bangladesh, mapped evidence from agriculture (interventions) to nutrition outcomes against six proposed pathways:

1) Agriculture as a source of food
2) Agriculture as a source of income for food and non-food expenditures
3) Agricultural policy and food prices affecting food consumption
4) Women in agriculture and intrahousehold decision making and resource allocation
5) Maternal employment in agriculture and childcare and feeding
6) Women in agriculture and maternal nutrition and health status

Overall, there is more evidence supporting the proposed pathways 1-3, particularly pathway 1, which pertains to subsistence agricultural production (food supply chains) for personal consumption by farmers households.

Pathways 2 and 3 relate to food environment dimensions involving economic accessibility to food. In contrast, pathways 4-6, which focus on the connections between maternal socioeconomic and nutritional status and child undernutrition, have more evidence concentrated within pathway 6, which addresses the hazardous conditions associated with agricultural labour.

Table 4. Summary of impact pathways from different types of interventions on dietary and nutrition outcomes through food systems, based on data from 87 relevant studies across 13 reviews and 71 interventions across 3 additional reviews

Types of intervention	Effects of interventions on food system	Proposed theoretical pathway	Dietary and nutrition outcomes	SCC Situation
Pathway Ⅰ: D-intake (16)				
D-intake (16)	NA	F-accessibility (4) C-awareness (1) S-health (3) S-care (1) C-behaviour (1)	N-malnutrition status (4) N-anthropometry (13) N-acute malnutrition (2) N-mortality (2)	Conflict (7) Economic crisis (1) Food crisis (1) Natural disaster (2) Seasonal hunger (1) SCC-sensitive country (3) Combination (1)
Pathway Ⅰ: D-intake ++ (21)				
D-intake + F-accessibility (1)	NA	F-affordability (1) C-behaviour (1)	N-acute malnutrition (1) N-mortality (1)	Seasonal hunger (1)
D-intake + C-awareness (1)	NA	NA	N-malnutrition status (1) N-anthropometry (1) N-acute malnutrition (1)	Conflict (1)
D-intake + S-health (5)	NA	C-behaviour (1)	N-anthropometry (1) N-acute malnutrition (4) N-mortality (1)	Conflict (3) Natural disaster (1) Combination (1)
D-intake + S-care (4)	NA	NA	N-malnutrition status (1) N-anthropometry (1) N-acute malnutrition (3) N-mortality (1)	Economic crisis (2) SCC-sensitive country (1) Natural disaster (1)
D-intake + F-other + S-health (1)	F-production (1)	NA	NA	SCC-sensitive country (1)
D-intake + C-awareness + S-care (3)	NA	C-behaviour (1)	N-malnutrition status (1) N-anthropometry (3) N-acute malnutrition (1)	Conflict (1) Natural disaster (1) SCC-sensitive country (1)
D-intake + S-health + S-care (5)	C-awareness (2)	C-behaviour (1)	D-child feeding (3) D-quality (2) D-quantity (2) N-anthropometry (1) N-acute malnutrition (2)	Conflict (2) Natural disaster (1) SCC-sensitive country (2)
D-intake + C-awareness + S-health + S-care (1)	NA	NA	N-anthropometry (1) N-acute malnutrition (1) N-mortality (1)	SCC-sensitive country (1)
Pathway Ⅱ: F-accessibility (27)/ F-other (6)				
F-accessibility (27)	F-production (1) F-availability (1) F-accessibility (7) F-affordability (7) C-behaviour (4) C-awareness (1)	F-production (1) F-market (1) F-availability (1) F-accessibility (5) F-affordability (2) F-other (2) C-behaviour (4)	D-quality (6) D-quantity (15) D-diversity (15) N-malnutrition status (2) N-anthropometry (7) N-acute malnutrition (2)	Conflict (5) Economic crisis (1) Food crisis (5) Natural disaster (1) SCC-sensitive country (11) Combination (3) Climate change (1)

Table 4. Summary of impact pathways from different types of interventions on dietary and nutrition outcomes through food systems, based on data from 87 relevant studies across 13 reviews and 71 interventions across 3 reviews (continued)

Types of intervention	Effects of interventions on food system	Proposed theoretical pathway	Dietary and nutrition outcomes	SCC Situation
		C-awareness (5) S-social (1)		
F-other (6)	C-behaviour (1[a]+2[b])	NA	D-quantity (1+1[b]) D-child feeding (1[b]) N-anthropometry (1[a]+1[b]) N-acute malnutrition (1[b])	SCC-sensitive country (6)
Pathway Ⅱ: F-accessibility ++ (5)				
F-accessibility + S-care (1)	NA	F-accessibility (1)	D-quantity (1) D-diversity (1)	Conflict (1)
F-accessibility + S-social (1)	F-other (1)	F-availability (1) C-behaviour (1)	D-diversity (1) D-quality (1) D-quantity (1)	Food crisis (1)
F-accessibility + S-policy (2)	F-accessibility (2)	NA	D-quantity (2)	SCC-sensitive country (2)
F-accessibility + C-awareness + S-care (1)	C-awareness (1)	NA	D-child feeding (1)	Conflict (1)
Pathway Ⅲ: C-awareness (2)/ C-behaviour (2)				
C-awareness (2)	C-awareness (1)	C-awareness (1)	D-child feeding (1) N-malnutrition status (1) N-anthropometry (1)	Natural disaster (1) SCC-sensitive country (1)
C-behaviour (2)	C-behaviour (2)	NA	D-diversity (1) N-malnutrition status (1)	SCC-sensitive country (2)
Pathway Ⅲ: C-awareness ++ (6)				
C-awareness + S-care (6)	F-production (1) C-awareness (2)	C-behaviour (1)	D-quality (1) D-quantity (1) D-diversity (1) N-anthropometry (5) N-acute malnutrition (1)	Conflict (4) SCC-sensitive country (2)
Pathway Ⅳ: S-health (3)/ S-care (18)/ S-policy (9)/ S-social (1)				
S-health (2)	C-awareness (1) C-behaviour (1) S-other (1)	C-behaviour (1)	N-acute malnutrition (1)	Conflict (2)
S-care (17)	C-awareness (3)	C-awareness (1) C-behaviour (2) S-health (1)	D-child feeding (8) D-quality (1) D-quantity (1) D-diversity (2) N-anthropometry (3) N-acute malnutrition (3) N-mortality (2)	Conflict (9) Natural disaster (4) SCC-sensitive country (3) Combination (1)
S-health + S-care (1)	C-awareness (1)	NA	NA	Conflict (1)
S-policy (9)	F-production (1) F-accessibility (1+1[a]) F-affordability (6+1[b]) C-behaviour (1)	NA	D-diversity (1) D-quality (1[b]) D-quantity (1+1[a]+2[b]) N-anthropometry (1)	SCC-sensitive country (9)
S-social + S-others (1)	NA	F-availability (1)	N-anthropometry (1)	Conflict (1)
Pathway Ⅴ: F-production (31)				
F-production (31)	F-production (17) F-market (2) F-accessibility (4)	NA	D-quality (15) D-quantity (13) D-diversity (4)	SCC-sensitive country (14) Climate change (17)

Table 4. Summary of impact pathways from different types of interventions on dietary and nutrition outcomes through food systems, based on data from 87 relevant studies across 13 reviews and 71 interventions across 3 reviews (continued)

Types of intervention	Effects of interventions on food system	Proposed theoretical pathway	Dietary and nutrition outcomes	SCC Situation
	F-availability (9) C-behaviour (2)		N-malnutrition status (4) N-anthropometry (2)	
Pathway ⩔: F-production ++ (9)				
F-production + F-other (1)	F-production (1)	NA	D-quality (1) D-quantity (1)	SCC-sensitive country (1)
F-production + C-awareness (8)	F-production (3) F-availability (1) F-accessibility (1) C-awareness (1) C-behaviour (3)	NA	D-child feeding (1) D-quality (4) D-quantity (5) D-diversity (2) N-malnutrition status (3) N-anthropometry (1)	SCC-sensitive country (4) Climate change (4)

[a] No positive effect; [b] Negative effect

The food system encompasses four main components: Supporting (S)- policy/social/health/care/others; Food supply chains (F)- production /processing/market/waste; Food environment (F)- availability/accessibility/affordability/utilisation and others; Consumer behaviour (C)- behaviour/preference/ awareness

The dietary and nutrition outcomes encompass two main categories: Dietary (D)-quality/quantity/diversity/child feeding; Nutrition (N)- status/anthropometry /acute malnutrition/mortality

"++": combined with other interventions

3.2.1 Interventions at consumption stage targeting dietary intake and child feeding (D-intake)

The first type of intervention targets dietary intake and child feeding alone (D-intake; supplementary feeding) or in combination with other components including supporting health/care systems or and consumer awareness (Composite D-intake, such as supplementary feeding in combination with health program) (see **Annex Table S5** and **S6**).

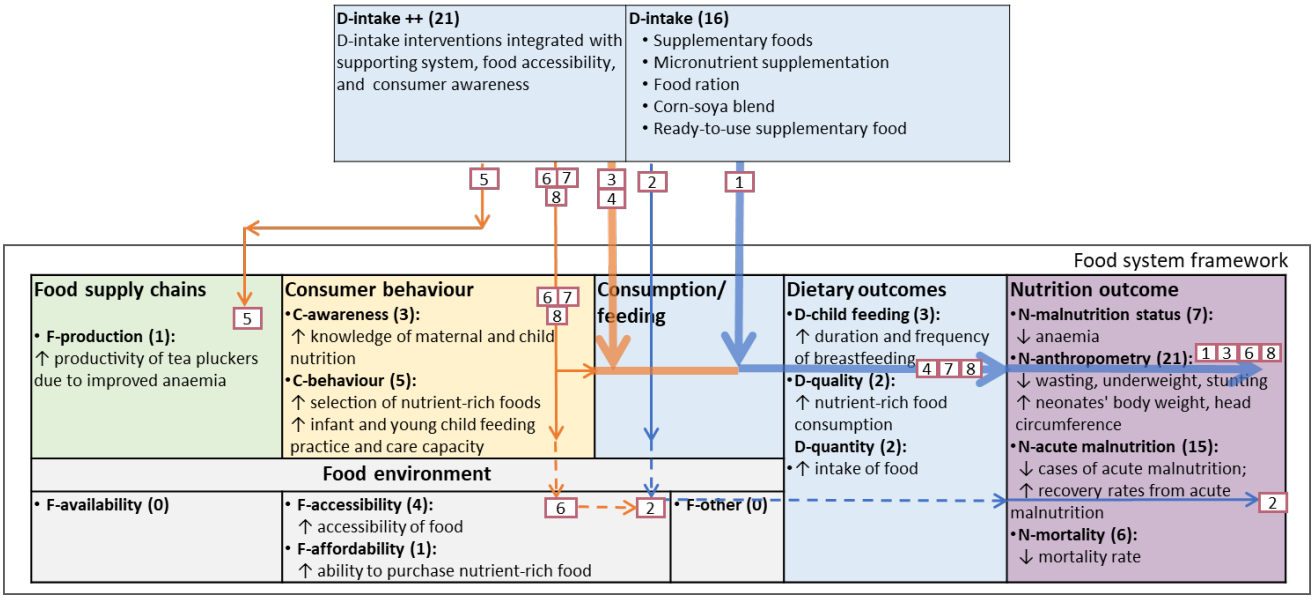
In conflict setting, relevant studies included in reviews of Shah *et al.*[28], Munyuzangabo *et al.*[30], and Kim *et al.*[33] showed that supplementary feeding is associated with improved nutrition outcomes (increased birthweight and height, head circumference, lower incidence of low birth weight, and improved global acute malnutrition recovery rates). Supplementary feeding interventions in other reviews[26,31,34,37,38] with a more varied SCC context also supported their effectiveness in improving nutrition outcomes (e.g., reductions in moderate and severe acute malnutrition, mortality, anaemia, wasting, stunting, and underweight, as well as increased HAZ and WAZ). Pradhan *et al.*[27] reviewed five supplementary feeding interventions, either standalone or in conjunction with health/nutrition education and medical care, in the context of natural disaster. They observed overall improvements in nutritional status (decreased anaemia) and anthropometric indicators (e.g., reduced rates of wasting, underweight, and stunting).

When considering all relevant original studies in the reviews, it was observed that, in general, for nutrition-specific interventions targeting dietary intake (D-intake) specifically (food/micronutrient/dietary supplement distribution or ration), improvement in nutrition outcomes were commonly observed (reported in 15 out of 16 studies; including increased birthweight and height, reductions in moderate and severe acute malnutrition, mortality, anaemia, wasting, stunting, and underweight, as well as increased HAZ and WAZ), but with little suggestion (measured or theorised) of involvement food supply chains and food environment (**Annex Table S5** and **S6**). Instead, the impact pathway starts from Diet (consumption) Component of the food system via direct food and nutrient intakes and child feeding to improved diets and nutrition. Similar observations were noted for Composite D-intake interventions involving dietary intake intervention and other components (mainly targeting

supporting system such as health programme and consumer behaviour such as counselling). There does not seem to be heterogeneity across SCC setting.

The impact pathways of D-intake and Composite D-intake interventions toward dietary patterns or nutrition outcomes, as listed for each study in **Annex Table S5** and **S6**, are illustrated in **Figure 2**. Eight paths are depicted, highlighting the major path (I-1), where D-intake interventions led to improved child growth and nutritional status through direct consumption/feeding. Additionally, major pathway I-3 illustrates Composite D-intake interventions combined with consumer behaviours and supporting system interventions led to improved child nutritional status and reduced acute malnutrition through direct consumption/feeding; pathway I-4 based on one study also led to improved dietary but not nutrition outcomes through direct consumption/feeding. Pathways I-7 and I-8 depict Composite D-intake interventions leading to improved dietary and nutrition outcomes through altering consumer behaviour (increased knowledge of maternal and child nutrition, improved IYCF practice, and selection of nutrient-rich foods). Other pathways (I-2, I-5, I-6) involved theorised involvement of food production (increased productivity of tea pluckers), increased food accessibility of food (physical access) and increased food affordability (increased ability to purchase nutrient rich food) with Composite D-intake interventions.

Figure 2. Impact pathways of interventions at consumption stage (I)



Dashed arrow: theoretical evidence only; "++": combined with other interventions
Boxed numbers correspond to different pathways.

3.2.2 Interventions targeting food accessibility (F-accessibility) and other food environment dimension (F-other)

The second type of interventions are those targeting food accessibility (F-accessibility; conditional/unconditional cash and food transfer and voucher, agricultural employment for household income), food accessibility interventions integrated with supporting systems (Composite F-accessibility; cash transfer in conjunction with nutrition and childcare education), and other dimension of food environment (F-other; women's employment in agricultural activities) (see **Annex Table S5** and **S6**).

In Pega *et al.*'s review[26] encompassing three studies across various SCC contexts, (unconditional) cash transfer led to increased dietary diversity in one study and reductions in MAM, SAM, and mortality in another study. Van Daalen *et al.*[32] also focused on the impact of interventions targeting food accessibility (conditional/unconditional

cash transfer, food vouchers, and income generating program). Based on 13 relevant studies[84–94,98,101] in that review, it was observed that these interventions effectively improved dietary outcomes such as increased dietary diversity (n= 10) and child meal frequency (n= 5); nutrition outcomes were less assessed, but some studies also reported reductions in acute malnutrition and increased weight gain. Review of Rabbani *et al.*[36] focused on conflict setting and found food vouchers transfer and IYCF promotion to increase dietary diversity, whereas health and nutrition service decrease moderate and severe acute malnutrition.

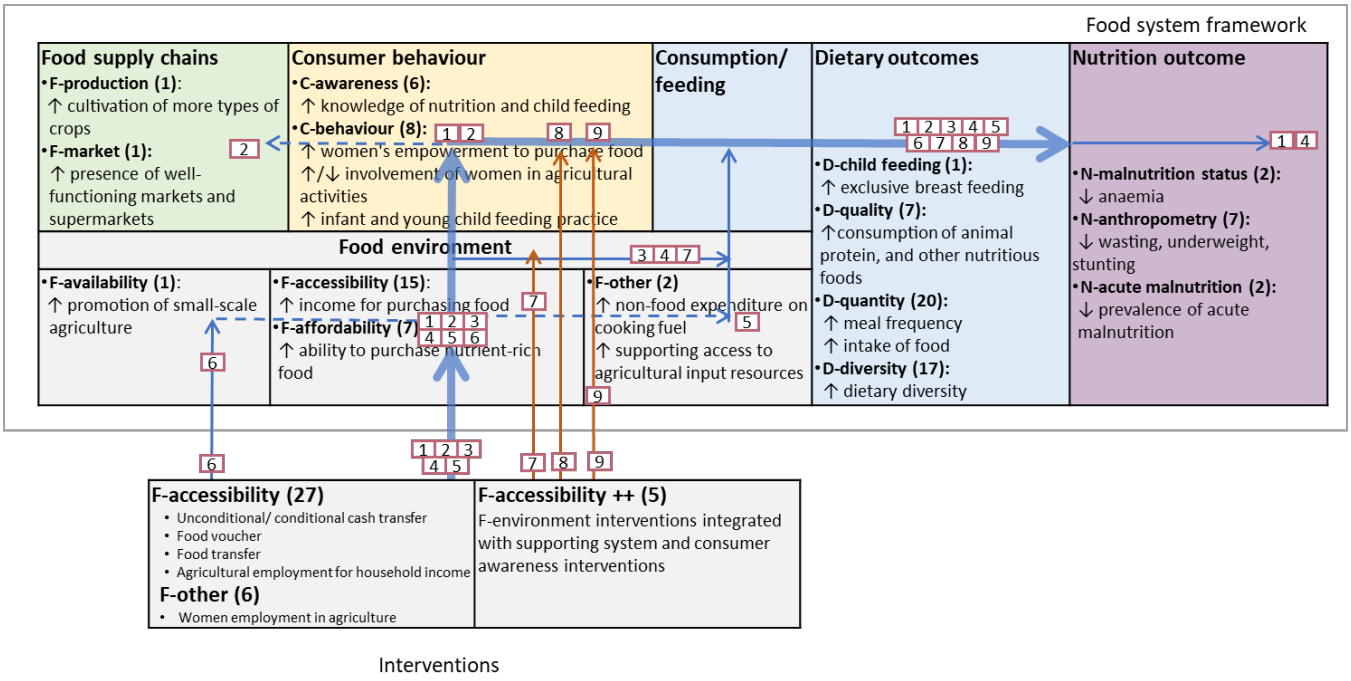
For the measured impacts on food system, the 13 studies in van Daalen *et al.*'s review[32] (**Annex Table S5**) in general found that improved dietary outcomes following conditional and unconditional cash transfer interventions were primarily due to increased food accessibility, increased income generating activities, increased food and non-food expenditure, changing consumer behaviours, and women's empowerment (greater control on food purchase).

When considering all relevant original studies and measured or theorised impacts on food system, F-accessibility (n= 27) and Composite F-accessibility (n= 5) interventions operate at the Food Environment and Consumer Behaviour components of the Food System framework through increasing food accessibility (increased income to purchase food) and food affordability (increasing ability to purchase nutrient-rich foods), primarily improving dietary outcomes (n= 36; increased dietary quantity, quality, and diversity) and, to a lesser extent, nutrition outcomes (n= 11; including reductions in acute malnutrition, stunting, wasting, mortality as well as increased weight gain) (**Annex Table S5** and **S6**). For those with an impact on nutrition outcomes, the food system pathways were theorised rather than measured. For measured food system impacts, the most frequently investigated components are food accessibility and affordability, whereas theorised food system pathways involved mostly other food environment dimensions and consumer knowledge and behaviour. No specific patterns associated with SCC context were observed, although only one study concerns a natural disaster specifically[86].

Six interventions were related to other aspects of food environment (F-other) involving women or mothers participating or employed in agricultural activities (**Annex Table S6**). These interventions may lead to excessive maternal activity, affecting newborn birth weight, or decreased healthcare seeking behaviour, leading to increased infant mortality rates. Regarding dietary outcomes, one study showed that mothers serving as pluckers in tea plantations increased dietary intake. However, another study indicated that the dietary intake of women engaged in agricultural activities varies by seasonality, such as decreased food intake and loss of women's body weight in lean season but increased childbirth weight in harvesting period.

The impact pathway of F-accessibility, Composite F-accessibility, and F-other interventions toward dietary patterns or nutrition outcomes of each study listed in **Annex Table S5** and **S6** are illustrated in **Figure 3**. Nine pathways were identified (ll-1 to ll-9). The main pathway is ll-1 where F-accessibility interventions improved dietary (increased dietary quantity, quality, and diversity) and nutrition outcomes (improved anthropometry and reduced acute malnutrition) through increased food accessibility and affordability and subsequently consumer awareness and behaviour. Pathway ll-4 was also associated with improved nutrition outcomes through affecting food environment but without documented evidence on impact on consumer behaviour. Pathway ll-2, ll-3, ll-5, ll-6, and ll-7 improved dietary outcomes (but not nutrition outcomes) through different dimensions of food environment. Pathways ll-8 and ll-9 are related to Composite F-accessibility interventions that improved dietary outcomes through affecting consumer behaviour, with ll-9 additionally affected other dimension of food environment (increased supporting access to agricultural input resources).

Figure 3. Impact pathways of interventions affecting accessibility and other food environment dimension (Ⅱ)



Dashed arrow: theoretical evidence only; "++": combined with other interventions
Boxed numbers correspond to different pathways. Negative impacts of F-other interventions were not depicted in this figure.

3.2.3 Interventions targeting consumers' awareness and behaviour (C-awareness and C-behaviour) and childcare and health supporting systems (S-care/S-health)

The third types of interventions in the SCC studies were linking care (S-care, such as providing nutrition counselling) and/or health systems (S-health, such as medical treatment) and using consumer behaviour (C-awareness, such as maternal and IYCF nutrition education) interventions to improve maternal and children's diets and nutrition. Since these interventions similarly operated at the Food System component - Consumer Behaviour through enhancing mothers' care capacity, health seeking, knowledge, and practices for IYCF, they are presented together in this section (see **Annex Table S5** and **S6**).

In Dall'Oglio et al.'s review[35] with eight relevant studies in the context of natural disaster or conflict, interventions targeting consumer behaviour and supporting system (promoting and supporting IYCF practices, postnatal care) were found to increase breastfeeding rates and reduce prevalence of general acute malnutrition and anaemia. Other reviews with more varied SCC contexts also showed that nutrition education[37], promotion of exclusive breastfeeding[37] or IYCF practice[38] positively impacted on both dietary (increased exclusive breastfeeding rate and duration and improved child feeding practices) and nutrition outcomes (reductions in anaemia, acute malnutrition, stunting, and mortality, as well as increased WAZ). A randomised trial in a Malawian refugee camp included in Als *et al.*'s review[29] showed that Water, Sanitation, and Hygiene intervention (water container with a cover and a spout to prevent household contamination of water) effectively reduced household contamination of water and subsequently diarrheal disease.

For measured impact on food system, five studies[104,106,112,116,129] (**Annex Table S5**) showed influence of S-care or S-health interventions such as mobile clinic and IYCF training on consumer awareness and behaviour. Of these, there studies[112,106,128] reported increased knowledge on exclusive breastfeeding following interventions on IYCF training, though their impacts on dietary intake or nutrition outcomes were not reported. Health and nutrition services provided by trained female Community Health Volunteers in conflict-afflicted Yemen[104] decreased SAM and MAM, possibly through increased caregiver knowledge on nutritious food and actual behaviour change

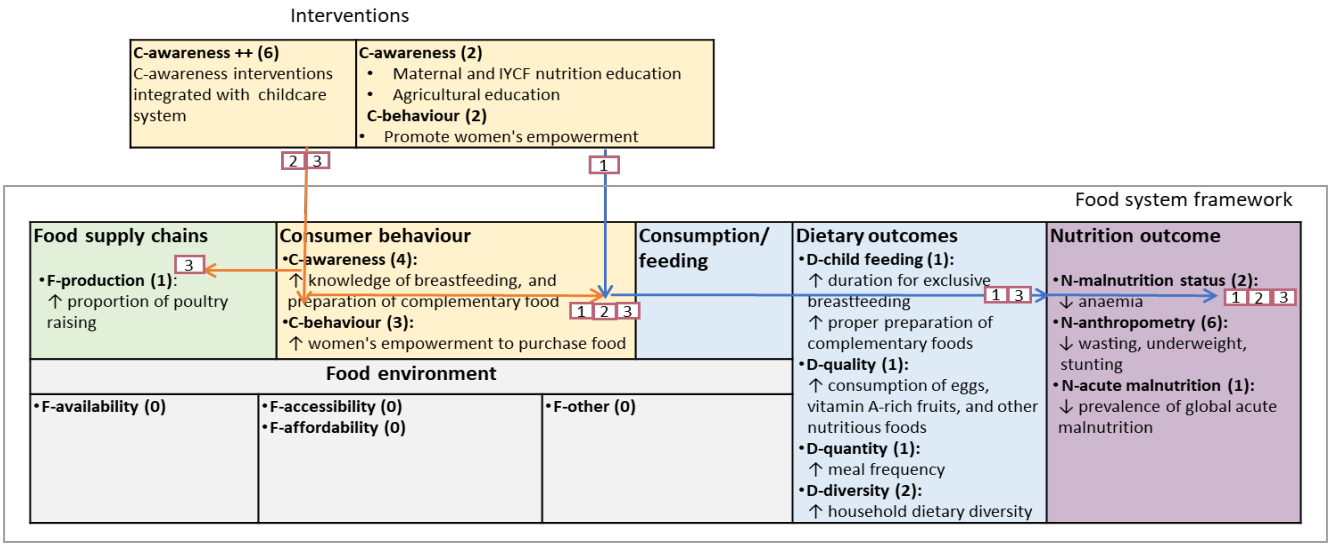
(using local foods for nutritious meal preparation). A study in Pakistan[116] showed that nutrition counselling by trained health workers improved dietary quality and child feeding and also increased WAZ among children, possibly through knowledge enhancement of the mothers (improved recall of recommendation of health workers and reported infant-feeding practices). A nutrition education intervention in China after Earthquake[43] increased duration for exclusive breastfeeding and decreased the prevalence of anaemia in children, with documented improvement in knowledge related to anaemia and knowledge and practice of complementary feeding.

When considering all relevant studies, these interventions significantly impacted on dietary and nutrition outcomes, with 13 studies reported improved diets (improved breastfeeding and complementary food feeding practices, increased dietary diversity, quantity, and quality) and 17 studies reported improved nutrition (including decreased anaemia, acute malnutrition, stunting, wasting, mortality, and increased WAZ and HAZ) from a total of 31 studies applying S-care/health and C-awareness/Composite C-awareness interventions (**Annex Table S5** and **S6**).

The impact pathways of C-awareness interventions and S-care/S-health interventions are illustrated in **Figure 4 and Figure 5**, respectively, based on data listed in **Annex Table S5** and **S6**. All three pathways (III-1, III-2, III-3 in **Figure 4**) identified for C-awareness /Composite C-awareness interventions showed that they led to improvements in dietary and nutrition outcomes through improving consumer awareness (increased knowledge of breastfeeding and preparation of complementary food) and consumer behaviours (increased women's empowerment to purchase food).

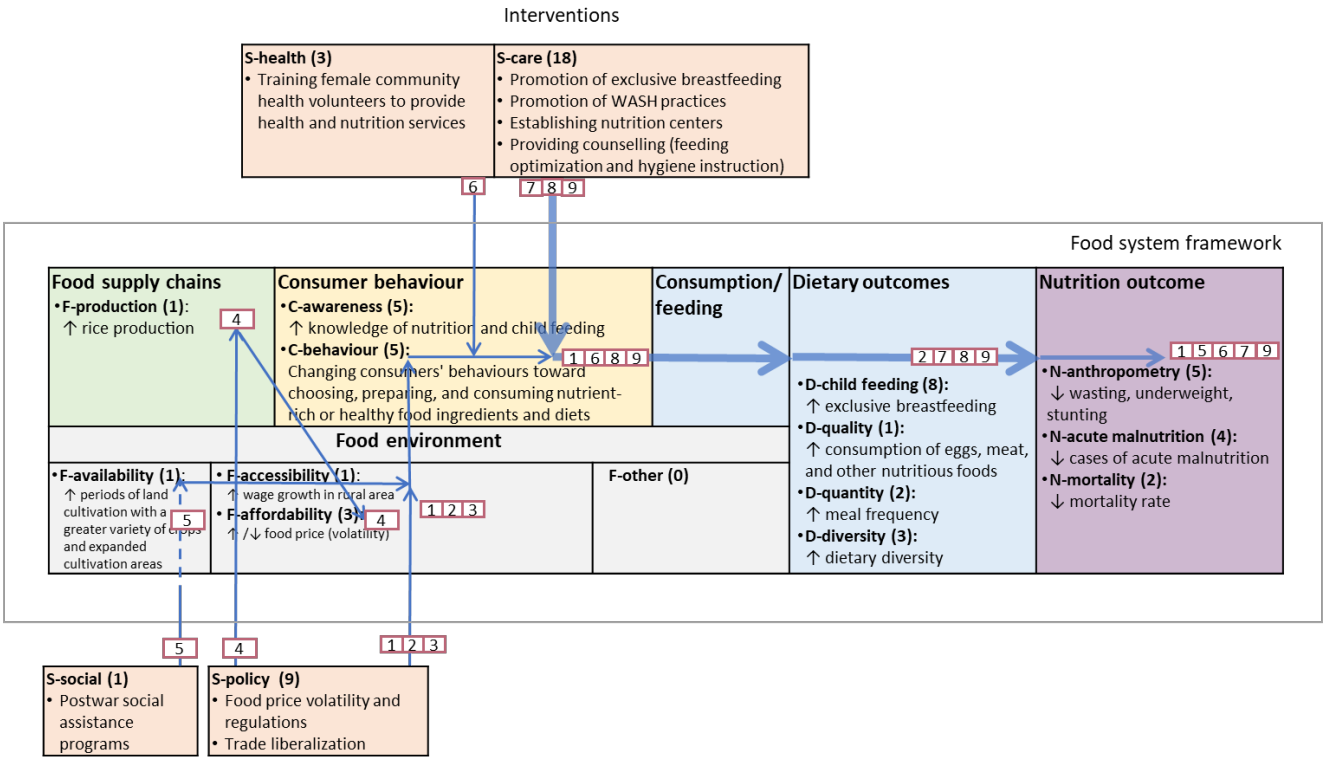
For S-care interventions, three pathways were identified (IV-7, IV-8, IV-9 in **Figure 5**). S-care interventions improved dietary and nutrition outcomes through directly affecting consumption and feedings (pathway IV-7) or through improving consumer awareness (improved knowledge of nutrition and child feeding) and consumer behaviour (choosing, preparing, and consuming nutrient-rich diet) (pathway IV-8 and IV-9). One pathway (IV-6 in **Figure 5**) was identified for S-health interventions, where they also led to enhanced consumer awareness and behaviour, and improved nutrition outcome.

Figure 4. Impact pathways of interventions targeting on consumers' awareness and behaviour changes (Ⅲ)



"++": combined with other interventions
IYCF: infant and young child feeding
Boxed numbers correspond to different pathways.

Figure 5. Impact pathways of interventions with supporting systems (Ⅳ)



Dashed arrow: theoretical evidence only; "++": combined with other interventions
WASH: water, sanitation, and health
Boxed numbers correspond to different pathways. Negative impacts of S-policy interventions were not depicted in this figure.

3.2.4 Interventions targeting policy supporting the food system: S-policy

Nine mentioned interventions in the 3 additional reviews focused on policy supporting food system (S-policy) interventions, including food price volatility and regulations, and trade liberalisations (**Annex Table S6**). Four pathways (IV-1, IV-2, IV-3, IV-4) involving food accessibility (increased wage growth in rural area) and food affordability (increased or decreased relative food price) were identified (**Figure 5**). Only pathway IV-1 involving rice expenditure intervention led to improved nutrition outcomes (decreased percentage of underweight children) through decreased rice expenditure and subsequently increased spending on other nutrition food, whereas pathway IV-2 involving food price volatility intervention led to increased dietary quantity due to increased food affordability. Pathway IV-3 and IV-4 led to increased food affordability (decreased rice price) and increased food accessibility (larger rural area wage growth), respectively, but did not have documented impacts on dietary or nutrition outcomes.

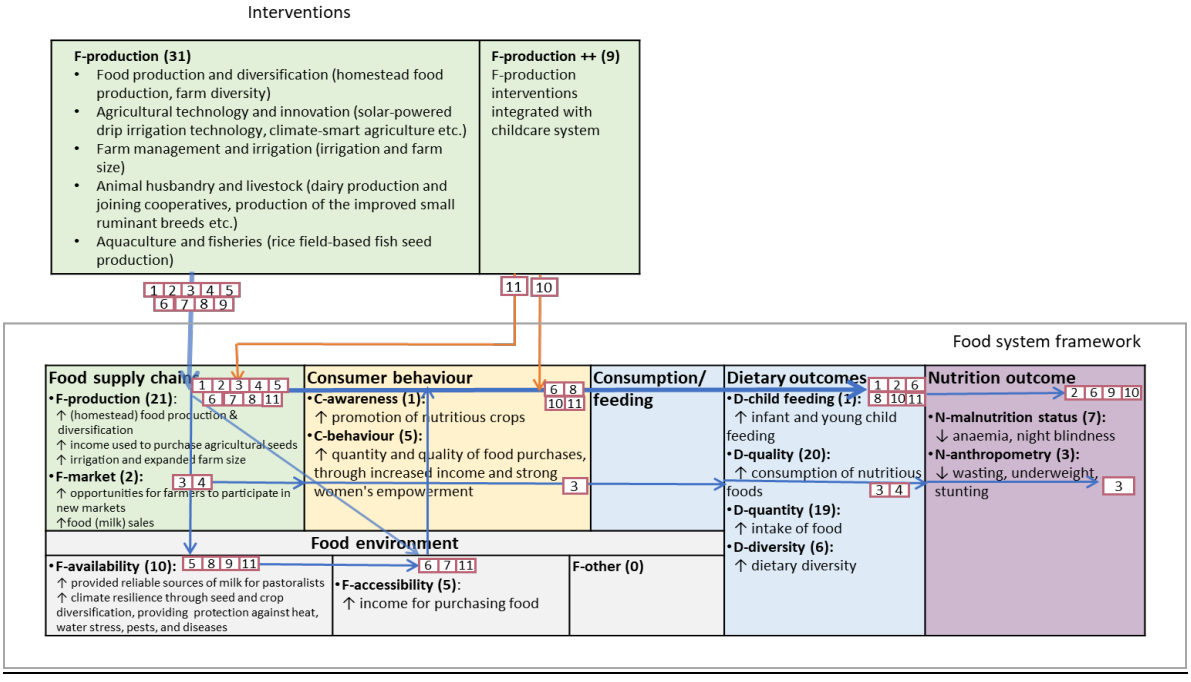
However, three studies involving fluctuations in food prices have repercussions on household income, food diversity, and consumption quantity (**Annex Table S6**; not depicted in Figure 5). Additionally, one study noted that trade liberalisation led to price hikes for several nutrition-relevant goods, consequently reducing protein and calorie intake. It is important to note that most of these studies involving agricultural policy interventions did not measure nutrition outcomes. Overall, S-policy interventions impacted on Food Environment and Consumer Behaviour components of the food systems, but with unclear and mixed impacts on dietary and nutrition outcomes.

3.2.5 Interventions targeting food production (F-production)

There were 31 studies/mentioned interventions related to food production (F-production) in the additional 3 reviews (**Annex Table S6**). Furthermore, 9 studies intervened by combining food production with consumer awareness, mostly involving women's participation in agricultural activities, thus increasing their influence in household decision-making and resource allocation (Composite F-production). These interventions were mapped by the authors in the theoretical pathways of agriculture as a source of farmer households' food or farmers' income, women empowerment in agriculture to nutrition, and the use of improved crops/ breeds for increased nutrient intake, resilience, or climate change adaptation. Concerning outcomes, 20 studies revealed improvements in dietary quality, 19 studies in dietary quantity, and 6 studies in dietary diversity. However, only 7 studies indicated improvements in nutrition status, such as increasing vitamin A status and reducing anaemia, with three studies demonstrating improvements in children's growth.

When the evidence from these food production interventions was mapped against our adopted food system framework, 11 pathways (V-1 to V-11), as listed for each mentioned intervention in **Annex Table S6**, are illustrated in **Figure 6**. Nine of these pathways (all except V-9 and V-10) passes through Food Supply Chains component of the Food System, increasing food production and diversification, agricultural input, irrigation, and farm size, and opportunities to participate in new markets. From there, the improved food production led to improved dietary outcomes (pathway V-1) and nutrition outcomes (pathway V-2) without further evidence of involvement of other food system elements. Four pathways (V-5, V-8, V-9, V-11) further increased food availability by providing reliable source of milk and increasing climate resilience through seed and crop diversification. Three pathways (V-6, V-7, V-11) involved increased food accessibility through increasing income for purchasing food. Pathways V-3, V-6, V-8, V-10, V-11 indicated that F-production interventions also led to changing consumer behaviour by increasing quantity and quality of food purchases through the increased income and women's empowerment. However, only five out of the 11 pathways (V-2, V-3, V-6, V-9, V-10) were associated with improved nutrition outcomes, whereas others (V-1, V-4, V-8, V-11) were only associated with improved dietary outcomes or have no evidence of impact on dietary or nutrition outcomes (V-5, V-7).

Figure 6. Impact pathways of interventions at food production stage (∇)



"++": combined with other interventions

Boxed numbers correspond to different pathways.

3.3 General impact pathways of nutrition interventions on dietary and nutrition outcomes

Integrating all evidence from all included (13+3) reviews (**Table 4**), the general pathways of these interventions are illustrated in **Figure 7** and listed below:

- **Pathway 1:** Interventions at the consumption stage through direct food consumption and child feeding. (I)
- **Pathway 2:** Interventions targeting consumer awareness and behaviour change through enhanced maternal care capacity, and health-seeking knowledge and practices for infant and young child feeding (IYCF). (III)
- **Pathway 3:** Interventions with supporting systems (health and childcare systems) targeting IYCF and maternal capacity. (IVa)
- **Pathway 4:** Interventions affecting accessibility by increasing income, purchasing power, and expenditure on nutrient-rich food. (IIa)
- **Pathway 5:** Interventions in food production and supply chains utilising agriculture as a source of food. (Va)
- **Pathway 6:** Interventions in food production and supply chains leveraging agriculture as a source of income. (Vb)
- **Pathway 7:** Interventions affecting food environments through the involvement of women in agriculture. (IIb)
- **Pathway 8:** Interventions with supporting systems (agri-food policy) affecting food purchasing, expenditure, and consumption. (IVb)

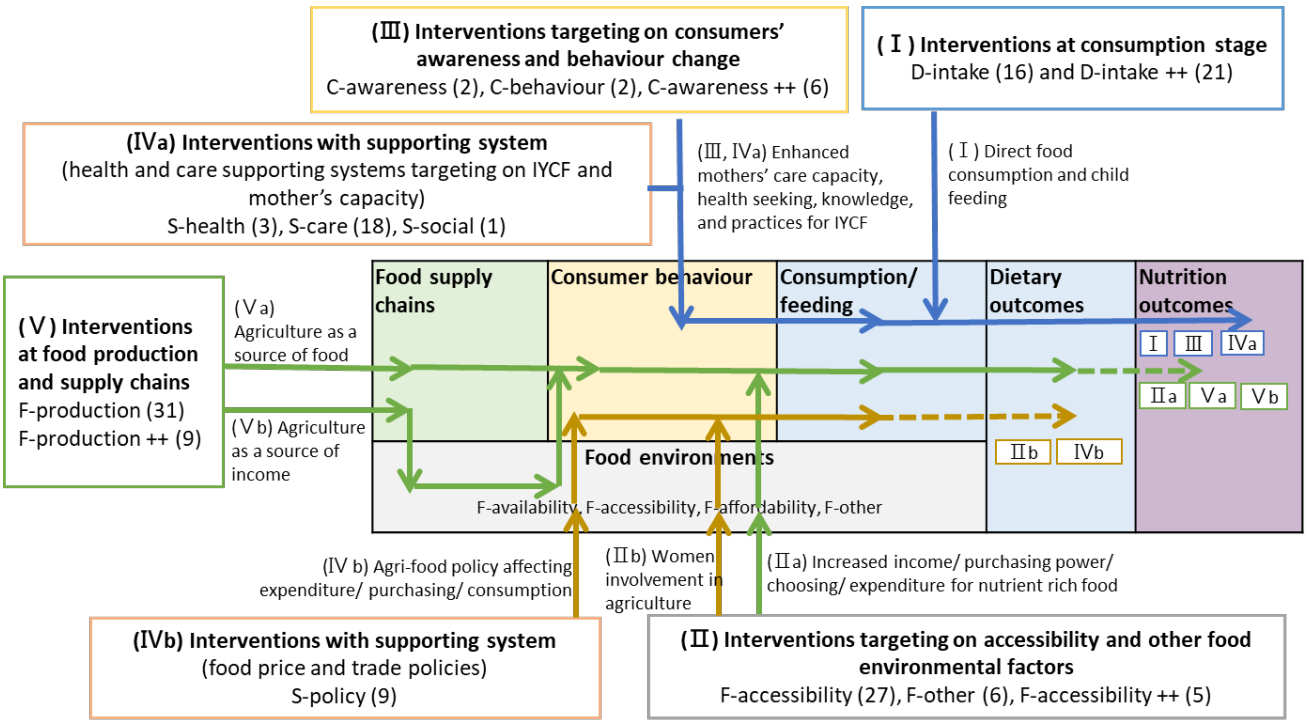
These general intervention impact pathways can be further grouped according to similarity in the pathways and their impacts on dietary and nutrition outcomes.

First, D-intake, C-awareness/behaviour, and S-care/health interventions **improved both dietary and nutrition outcomes (general pathways 1-3 [I, III, and IVa] in blue in Figure 7)**, operating through Food System-Consumer Behaviour (pathways lll, IVa: enhanced mothers' caregiving capacity, health-seeking behaviour, knowledge, and practices for IYCF) and Food System-Diet (pathway l: direct food consumption and feeding) components.

Second, F-production and F-accessibility interventions primarily **improved dietary and, to a lesser extent, nutrition outcomes (general pathways 4-6 [IIa, Va and Vb] in green in Figure 7)**, operating within the Food System-Food Supply Chains (pathway Va: agriculture as a source of food) and Food Environment (pathway lla: increasing income, purchasing power, direct purchasing, and expenditure for nutrient-rich foods; pathway Vb: agriculture as a source of income) components of food system.

Third, S-policy interventions involving food price and trade policies and other food environment interventions (F-other) involving women employment in agriculture had **mixed impacts (both positive and negative) on dietary outcomes and very limited reported impact on nutrition outcomes (general pathways 7 and 8 [llb and lVb] in brown in Figure 7)**, operating within Food System-Food Environment (pathway IVb: changes in food prices and subsequent changes in relative expenditure on different foods) and Consumer Behaviour (pathway IVb: increased household spending on non-rice foods; pathway llb: decreased healthcare seeking and excessive maternal activity from farm work) components.

Figure 7. General pathways from interventions to dietary and nutrition outcomes through food system



Blue arrow: interventions improved both dietary and nutrition outcomes; Green arrow: interventions improved mainly dietary outcomes; Brown arrow: interventions had mixed impacts on dietary outcomes; Dashed arrow: weak or mixed impacts on dietary/nutrition outcomes

"++": combined with other interventions

IYCF: infant and young child feeding

Discussion

In our systematic overview, we examined 16 reviews assessing the effects of nutrition interventions carried out in the context of SCCs on dietary and nutrition outcomes in LMICs, specifically through food supply, food environment, and consumer behaviour. Our study identified 5 types of interventions and 8 general impact pathways leading to dietary and nutrition outcomes.

A key finding is that nutrition-related interventions, especially those targeting dietary intake, consumer behaviour, childcare and health system, food production, and food accessibility, effectively reduce the adverse effects of SCC on dietary patterns and malnutrition in LMICs (see Pathway 1-6 in Box 1 and Figure 7). However, formal investigations of impacts on the food system were infrequent across these studies.

Our results align with other reviews focusing on more generalised settings. In a systematics review of interventions aimed at enhancing food accessibility in LMICs[129], it was noted that interventions targeting increased purchasing power showed promise in improving food security, though evidence regarding their impact on household food expenditure and wasting is limited. Interventions addressing food prices revealed that both food vouchers and food and nutrition subsidies enhanced dietary diversity, with food vouchers also showing a reduction in stunting. Social support interventions show minimal impact on wasting and stunting, and their effects on food security and dietary diversity are highly uncertain. Of note, none of the interventions addressed infrastructure and transport affecting physical access to food outlets. These results are in general concordant with our observations in SCC context, where dietary outcomes are more common and pathways through food systems are probable but not supported by strong causality. We found that agricultural interventions improved dietary outcomes (increased quantity, quality, diversity) and to a lesser extent nutrition outcomes (reduction in anaemia, wasting, underweight, and stunting) by increasing food production and agricultural income, consistent with a review focusing on nutrition-sensitive agriculture in LMICs[132].

Nutrition-specific interventions like food aid, feeding programmes, and supplementation are frequently employed in areas affected by SCC due to their quick and visible impact on malnutrition[131,132]. In our review, we also find that these interventions are effective in improving nutrition outcomes (Box 1 and Figure 7). However, nutrition-sensitive interventions, such as food and agricultural production, are critically important but often underutilised in SCC-affected areas[133]. We found that such interventions are more frequently associated with improved dietary outcomes, but evidence suggesting their impacts on nutrition outcomes are limited. These interventions encounter numerous challenges (see Box 1), such as infrastructure damage, security concerns, limited resources, population displacement, market disruptions, and a tendency to prioritise short-term relief over long-term development.

While no interventions directly and specifically targeting food availability and affordability were identified, other interventions identified in this study, such as nutrition-sensitive agriculture (e.g., homestead food production and livestock ownership), cash-transfer, and food price regulations, also targeted and influenced these dimensions of food environment by impacting food production and accessibility. For example, homestead food production and livestock ownership increased food production and subsequently food availability, whereas cash-transfer and food price regulations improved food affordability by increasing economic access to food. In the 2023 edition of The State of Food Security and Nutrition in the World[134], it has been estimated that 42% of the global population could not afford a healthy diet in 2021, which can be attributed to both rising cost of a healthy diet and declining disposable income in many countries. Other factors influencing food affordability include food production for own consumption[134], proximity to food markets[134], and the relative cost of nutrient-dense foods compared to calorie-dense staple foods[135]. Our observations indicate that cash or food voucher transfers, along with income generation programmes, have improved dietary outcomes in SCC settings. This suggests that improving economic access to food can mitigate the adverse effects of SCC on food price and availability.

Box 1. Effects and challenges of the identified intervention pathways

1. Direct consumption and child feeding (Pathway 1): Interventions focused on direct food consumption and child feeding, such as supplemental feeding programmes and the distribution of fortified foods, improve child nutrition directly and are particularly important for reaching the most vulnerable groups, such as infants and young children, who are at high risk of malnutrition during SCC[139]. While effective in the short term, these interventions may have limited impact on long-term nutritional outcomes if not integrated with broader food security strategies[140] that address the underlying causes of food insecurity, such as poverty and limited access to diverse foods.

2. Consumer awareness and behaviour change (Pathway 2): Interventions aimed at enhancing maternal care capacity and health-seeking behaviours are essential for promoting long-term nutritional outcomes[141]. Education programmes focused on infant and young child feeding (IYCF) practices, such as exclusive breastfeeding and complementary feeding, improve dietary diversity and reduce malnutrition rates, as observed in this study and other reports from both stable and crisis-affected settings[142,143]. In SCC contexts, the effectiveness of behaviour change interventions can be limited by the lack of access to resources and support systems[141]. Therefore, these interventions must be adaptable to crisis conditions. Interventions that incorporate community-based support, such as peer counselling and mother-to-mother support groups, have been particularly effective in enhancing IYCF practices in LMICs[51,142].

3. Supporting systems for IYCF (Pathway 3): Integrating IYCF interventions with broader health and childcare systems, such as training female community volunteers, promoting WASH practices, establishing nutrition centres, and implementing post-war social assistance programmes, is crucial for improving maternal and child nutrition[104,126]. Health systems that provide routine monitoring, counselling, and support for maternal and child nutrition are better equipped to address the nutritional needs of vulnerable populations during crises[144]. Systems that can adapt to and recover from crises are more likely to maintain the delivery of essential nutrition services, such as immunizations, growth monitoring, and nutritional counselling, as evidenced in this study and during the COVID-19 pandemic[147]. In many LMICs, access to health and childcare services is often limited, especially during crises. Interventions that focus on improving access to these services, such as mobile health units or community health workers, can help ensure that mothers and children receive the support needed to maintain good nutrition during times of crisis[104,148,149].

4. Income and food accessibility (Pathway 4): In LMICs, income volatility caused by SCC can significantly impact food security. Studies show that during economic shocks, such as the COVID-19 pandemic, many households shifted their spending from nutrient-rich foods to cheaper, less nutritious options, worsening nutritional status[150]. Targeted cash transfer programmes can stabilize household purchasing power during crises, helping maintain expenditure on nutrient-rich foods and improving dietary outcomes[83,85]. These interventions are particularly effective in settings where markets remain functional[130]. However, in SCC contexts, market access can be severely disrupted. In contexts where immediate food access is compromised due to market disruptions or extreme poverty, food vouchers and food aid interventions play a critical role by enabling households to access essential food items, including nutrient-rich foods, during crises[8458]. Public food procurement is emphasized for building resilient food systems and maintaining market access, especially to ensure the availability of nutrient-rich foods during disruptions[151]. Additionally, implementing short food supply chains can enhance food system resilience and ensure food security during crises[152].

5. Agriculture as food source (Pathway 5): Agriculture plays a crucial role in contributing to food security and nutrition, particularly through home-based or own production, which directly addresses food affordability by bypassing market dependencies[40,41]. However, in the face of SCC, the ability of agriculture to maintain food security can be severely compromised[154–156]. The resilience and sustainability of agricultural systems are critical in determining agriculture's effectiveness in generating positive nutritional outcomes during SCC[157,158]. Sustainable agricultural practices, such as crop diversification and the adoption of climate-resilient farming techniques, are essential for maintaining food production amid these challenges. Households using these practices are better able to sustain food availability and dietary diversity during crises, thereby mitigating the adverse effects of SCC on diets and nutrition[159]. Additionally, access to agricultural resources, such as seeds, fertilizers, and tools, is vital for restoring productivity post-crisis. External support in the form of emergency agricultural aid[159] and initiatives that encourage younger generations to participate in agriculture[160] have proven effective in helping households recover and improve dietary outcomes following disruptions.

6. Agriculture as income source (Pathway 6): Agriculture as a source of income holds significant potential for improving food security, diets, and nutrition in LMICs[40,41]. However, economic disruptions, such as market collapses and, inflation can lead to substantial fluctuations in food prices and agricultural income[147,161]. To enhance the effectiveness of agricultural income in improving dietary outcomes, it is essential to implement risk management strategies including income diversification, access to microinsurance, and the development of savings mechanisms, all of which can help stabilize household income during economic instability[163]. Interventions providing financial tools, resources, and livestock diversification have been shown to mitigate the negative impacts of income volatility on food security[164,165]. The control of agricultural income by women plays a critical role in effectively translating income into improved nutrition. Studies have shown that when women manage agricultural earnings, they are more likely to prioritize spending on food and nutrition, leading to better dietary outcomes for their families[166]. However, in LMICs, women often lack control over agricultural income, limiting the potential of this pathway to achieve significant nutritional improvements[165,167].

Box 1. Effects and challenges of the identified intervention pathways (continued)

7. Women in agriculture (Pathway 7): Empowering women in agriculture has the potential to significantly improve household food security and dietary outcomes, particularly in LMICs[40,41]. Women often play a critical role in food production and household nutrition, making their empowerment essential for achieving positive nutritional outcomes[168]. However, women involved in agriculture frequently face the dual burden of agricultural work and caregiving responsibilities, which can reduce their ability to contribute effectively to household food security[169,170]. During SCC, these burdens can intensify, further suppressing dietary diversity and nutrition outcomes for their families[40,41]. Access to social protection programmes and nutritional support is crucial in mitigating the negative impacts of crises on both maternal and child nutrition. These interventions can provide the necessary support for mothers to continue their agricultural work while ensuring their children receive the nutrition and care they need[172].

8. Agri-food policies (Pathway 8): Agri-food policies are instrumental in shaping food security and dietary outcomes, especially in LMICs. In SCC contexts, existing agri-food policies often fail to address the complex challenges of food security[148,149]. In our study, policies on food prices and trade showed weak evidence of effectiveness in improving dietary outcomes [40,41]. During crises, the disruption of markets and supply chains can severely undermine the impact of agri-food policies aimed at improving nutritional outcomes. For example, studies have shown that during the COVID-19 pandemic, the inability of existing agri-food policies to adapt quickly led to increased food insecurity and reduced access to diverse and nutritious foods in many low-income settings[161]. Policies that are not adaptive to rapidly changing conditions can exacerbate food insecurity and limit access to diverse and nutritious foods. While emergency food aid is crucial during crises, policies that also focus on long-term nutritional goals are more likely to improve dietary outcomes[149]. Integrating nutrition-sensitive approaches into agri-food policies can help ensure that immediate relief efforts do not overshadow the need for sustainable food systems that support dietary diversity[173]. Effective agri-food policies in SCC contexts must be inclusive, considering the needs of vulnerable populations, including women, children. Inclusive policies are more likely to result in positive dietary outcomes, as they address the root causes of food insecurity and malnutrition[174].

Strengths and limitations

This systematic review employed a comprehensive search strategy. By focusing on published literature, we aimed to provide a robust evidence base. However, searching the grey literature may have yielded additional relevant information. While our specific study contributes to a better understanding of the effects of nutrition interventions in the context of SCC and LMICs (in contrast to more generalised settings) on maternal and child nutrition outcomes through food systems, it is not exhaustive. Nevertheless, the included studies encompass a variety of interventions and SCC contexts commonly studied in previous systematic reviews, highlighting intervention efforts that warrant further impact assessment.

In addition, assessing and summarising the intermediate connections within each pathway proved challenging due to the diversity of study designs, scopes, and outcomes. The analysis was constrained by heterogeneous outcome indicators and a scarcity of studies specifically examining food systems components. Many studies either focused on food systems' components without linking to nutrition outcomes or vice versa, complicating the establishment of robust connections between nutrition interventions and outcomes, which posed a challenge in establishing linkages from several interventions and their respective entry points in the food system, to nutrition outcomes. However, we acknowledge that measuring the nutrition outcomes of food system interventions in LMICs impacted by SCC is inherently difficult due to the complex and interdependent nature of food systems[133,136,137]. Moreover, data collection in SCC contexts is often constrained by insecurity, population displacement, limited access to affected areas, and disruptions to monitoring systems. The unclear long-term impact of interventions on nutrition, variable data quality, indirect effects on nutrition, behavioural influences, and challenges in establishing control groups further complicate these assessments. This is especially so for nutrition-sensitive interventions targeting food supply chains and food environments. In addition, these interventions are influenced by a range of factors, including environmental, economic, and health-related aspects, necessitating multi-sectoral and innovative monitoring techniques to accurately evaluate their effectiveness.

Moreover, most included reviews were rated as having low quality based on the AMSTAR 2 assessment. This suggests methodological limitations influenced by the availability of evidence and the quality of the original

studies. While we did not re-appraise the original studies, many reviews reported moderate to high risk of bias. For instance, only 30% of the studies included Ghodsi *et al.*'s review[34] were rated as having an low risk of bias, whereas studies with high risk of bias were highly prevalent in the review by Pradhan *et al.*[27]. In the two hand-searched relevant reviews conducted in India and Bangladesh, a large majority of the studies were descriptive or cross-sectional in nature, with very few employing randomised controlled or quasi-experimental designs. This also reflects the challenges associated with conducting nutrition interventions through randomisation and blinding, especially when implemented in communities, while SCC settings may impose further difficulties due to ethical reasons.

Implications for research and policy

This review of nutrition interventions within SCC contexts in LMICs offers several insights for decision-makers navigating complex intersection of nutrition, SCC, and food systems:

1) Implement interventions targeting dietary intakes: Interventions targeting dietary intake (pathway 1), such as food supplementation, have shown tangible benefits in improving nutrition outcomes, underscoring their effectiveness. Decision makers should support these interventions and ensure high coverage to address malnutrition effectively.

2) Implement consumer behaviour interventions and concurrently strengthen childcare and health systems and infrastructure: Interventions targeting consumer behaviour, like nutrition education, and supporting systems, such as promotion of IYCF and the establishment of support centres (pathways 2 and 3), have been shown to effectively enhance dietary and nutrition outcomes by raising consumer awareness and facilitating behavioural changes.

3) Implement interventions enhancing food accessibility: Interventions enhancing food accessibility (pathway 4) through mechanisms like cash transfers and income generation programmes have demonstrated promise in improving dietary diversity (and to some extents mitigate malnutrition) mainly through increasing food affordability and income. Thus, such initiatives should be scaled up to ensure equitable access to nutritious food, particularly among vulnerable populations affected by SCC.

4) Enhance agricultural investment: Our review highlights the pivotal role of agriculture (pathways 5 and 6) in improving nutrition outcomes through home gardening/own production, food production, food price, and income generation, emphasising the importance of interventions such as crop diversification, climate-smart agriculture and resilient livestock breeding. Thus, nutrition-sensitive agricultural interventions should be invested to enhance food security and to promote sustainable nutrition practices.

5) Integrate nutrition-specific and nutrition-sensitive interventions: Development and implementation of comprehensive strategies that blend both nutrition-specific (pathway 1-3) and nutrition-sensitive (pathway 4-6) interventions could be considered to reap benefits from both approaches. While nutrition-specific interventions involving direct nutrient or food supplementation are found to be the most effective in improving nutrition outcomes in this study, such effects may be short-lived and prone to relapse if the root causes of malnutrition are not addressed[138].

6) Prioritise equity and inclusivity: Interventions should ensure marginalised groups have equitable access to essential services and resources. Policies should empower women in agricultural sectors (pathway 7) by providing equal access to resources like land and credit, while reducing their risks of being exposed to agricultural hazards, to enhance their role in household food security and nutrition. Agri-food policies (pathway 8) needs to

be inclusive, addressing the needs of vulnerable populations, and adaptable to changing conditions, particularly during crises, to remain effective.

A need to improve data monitoring and outcome assessment was also identified through this review, which has been acknowledged in recent reports in resilience, food crises, food systems, food policy[139]. Decreasing humanitarian funding and rising delivery costs exacerbates food insecurity and forces the adoption of coping strategies that may harm livelihoods and increase malnutrition risks, especially among women and children[140]. Thus, continued investment in funding in crisis contexts is essential to strengthen relevant systems and to support communities through transitions[139].

Collaboration among governmental entities, non-governmental organisations, international bodies, and local communities is indispensable for the effective implementation and longevity of effective interventions and policies, fostering synergistic partnerships that harness resources, expertise, and collective action to mitigate the impact of malnutrition in SCC-affected populations. This resonates with key recommended actions to achieve 'nutrition equity' in the Global Nutrition Report 2020[141].

Our findings underscore the urgency of adopting a multifaceted approach to address the complex challenges facing nutrition during SCC settings in LMICs. By embracing an integrated approach grounded in evidence-based interventions, decision makers can effectively navigate the intricate challenges of nutrition in these situations, advancing food security, dietary diversity, and sustainable nutrition practices for vulnerable populations.

Conclusion

This systematic review of reviews examining the effects of nutrition interventions within the context of SCC on dietary and nutrition outcomes in LMICs sheds light on the current state of the knowledge about the effects of these interventions in mitigating the adverse impacts of SCC on nutrition. Interventions targeting dietary intake, consumer awareness, and health or childcare systems showed potential to improving nutrition through enhanced consumption and behaviour changes. Interventions focused on agricultural food production and economic accessibility showed potential to improve dietary, and to a lesser extent nutrition outcomes, by increasing own sources of food, income and purchasing power. Interventions involving women in agriculture and broader agri-food policies showed mixed results.

The findings point to the need for comprehensive strategies that integrate nutrition-specific and nutrition-sensitive interventions, potentially tailored to the unique contexts of SCC-affected populations, to address malnutrition effectively. Limited available evidence and overall low quality of the studies assessed emphasise, additionally, the need for cautious interpretation of the findings. Moving forward, future research should prioritise rigorous methods and comprehensive impact evaluation, to enhance the evidence base and further inform the design and development of effective strategies for addressing malnutrition in LMICs affected by SCC.

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