# Drivers of persistent high rates of undernutrition in the Sahel – a systematic literature review

NUTRITION RESEARCH FACILITY
Knowledge and Research for Nutrition

March 2024

## 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.

Contact: nrf@agrinatura-eu.eu


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# List of Acronyms

| Acronym | Description |
|---|---|
| AM | Acute Malnutrition |
| BF | Burkina Faso |
| BMI | Body Mass Index |
| CAM | Cameroon |
| CHA | Chad |
| CI | Côte d'Ivoire |
| CINAHL | Cumulative Index to Nursing and Allied Health Literature |
| COVID-19 | Coronavirus Disease 2019 |
| EED | Environmental Enteric Dysfunction |
| ETH | Ethiopia |
| EU | European Union |
| FAO | Food and Agriculture Organisation of the United Nations |
| GAM | Global Acute Malnutrition |
| GAMB | Gambia |
| GHA | Ghana |
| GAIN | Global Alliance for Improved Nutrition |
| GUI | Guinea |
| HLPE | High Level Panel of Experts |
| IBSS | International Bibliography of Social Science |
| IFPRI | International Food Policy Research Institute |
| LMICs | Low- and Middle-Income Countries |
| MAL | Mali |
| MAU | Mauritania |
| MDD-W | Minimum Dietary Diversity for Women |
| MUAC | Mid-upper Arm Circumference |
| NGA | Nigeria |
| NIG | Niger |
| OECD | Organisation for Economic Cooperation and Development |
| PAHs | Polycyclic aromatic hydrocarbons |
| PICOS | Population, Intervention, Comparison, Outcomes and Setting |
| SD | Standard Deviation |
| SEN | SEN – Senegal |
| UNDP | United Nations Development Program |
| UNICEF | United Nations International Children's Emergency Fund |
| WASH | Water, Sanitation and Hygiene |
| WFP | World Food Program |
| WHO | World Health Organisation |
| WRA | Women of Reproductive Age |

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# Executive Summary


**Context**

Considering the persistent prevalence of undernutrition in the Sahel region, local decision-makers recognise the challenges in addressing this public health concern. This recognition is informed by the fact that the notable aggregation of regular and sustained nutrition interventions, supported by both national authorities and international humanitarian organizations, has resulted in limited success in mitigating undernutrition.

The Nutrition Research Facility organised a consultation with decision-makers from West Africa to capture their demand for scientific input. Among the prioritised questions was: "*Why does high prevalence and incidence of undernutrition (stunting, wasting, micronutrient deficiencies) persist in Sahelian countries, even when regularly supported by multiple nutrition programs?*" In this context, a comprehensive research study titled "Drivers of persistently high rates of undernutrition in the Sahel – a comprehensive contextualised research" was implemented to contribute to explaining i) what are the main drivers leading to this persistence of high prevalence and incidence? and ii) what are the contextual and structural/systemic drivers that are reducing the implementation effectiveness of nutrition interventions across the Sahel?, explaining the aforementioned continued and high prevalence incidence of undernutrition in that context. The identification of such critical drivers is utmost needed for an appropriate refinement of policies and targeted programs, in line with the EC's commitments and Action Plan to reduce stunting in children under five by at least 10% of the World Health Assembly goal by 2025.

Here we present the results of a first component of the comprehensive Research Study. The main objective is to review and discuss what is published about drivers of undernutrition in the specific context of the Sahel. The subsequent steps will address the same question using different methodologies and perspectives. Component two will employ machine learning algorithms to assess and expand the findings from Component 1, using available geocoded data on the region. Component three aims to provide contextualization*, in loco*, of the main drivers identified through qualitative interviews with beneficiaries of past and current programs implemented in two selected Sahelian countries.

Another complementary study will look at the implementation effectiveness of nutrition-related programs in the Sahel and analyse design gaps in actions and investments by examining the extent to which programming is integrated and multisectoral.

**Methodology**

A systematic mapping review of drivers of undernutrition in children and women of reproductive age reported in the region was conducted, targeting literature review publications. Data analysis followed the "best-fit" framework-synthesis approach. Given the particular focus of this study on the Sahelian region, the *a priori* framework used to guide the review and outline the findings was the "Acute malnutrition in Africa's drylands," developed by Young et al. (2020) and derived from the "UNICEF conceptual framework of undernutrition". This framework adds dimensions related to characteristics of acute malnutrition in Africa's drylands, covering countries in the Sahel, accounting for contextual phenomena by adding "systemic dimensions" such as livelihood systems, systems and arrangements of formal and informal institutions, and environment and seasonality.

After database searches, duplicates removal, eligibility checking and citation tracking, a total of 72 publications were included in the systematic review. From these, 60 covered drivers of undernutrition only in children, seven covered drivers of anaemia only in women of reproductive age, and five covered undernutrition drivers in both populations.

**Findings**

The main research output of this study is a list of 76 drivers of undernutrition in the Sahel and in Sahelian countries, based on evidence from published literature. The countries from where more information is available are those where population surveys such as the Demographic Health Survey are frequently implemented to monitor health and Development outcomes, *i.e.,* these standardised data collections are important given the scarcity of local research and quality data. This is reflected in many drivers for which information is commonly collected in those surveys, such as low dietary diversity, minimum acceptable diet, nutritional status of both the child and the mother, age, sex of the child, and other immediate drivers. There is, however, a lower availability of data for indicators in dimensions framed in the underlying and basic/systemic causes.

Despite the similar number of drivers mapped in each of the three causes (immediate, underlying, and basic/systemic), the results show a lower number of countries, outcomes, and publications to which "underlying drivers" are reported. Noticeably, the number of publications reporting "immediate drivers" was significantly higher than the number of publications reporting "underlying" and "basic/systemic" drivers. Moreover, a bias is observed within the three causes of undernutrition. The nature of publications retrieved indicates limited research outputs on dietary intake, household food security and environment & seasonality, and emphasizes a higher availability of drivers within the dimensions disease, health & care environments, and arrangements of formal and informal institutions. Concerning immediate undernutrition causes, "Disease" was the dimension showing the highest frequency for all publications. Regarding underlying undernutrition drivers, "insufficient health services and unhealthy environment" presented the highest frequency of identified drivers among studies reporting on all outcomes. "Livelihood systems" was the basic/systematic dimension mostly reported.

We also provide a list of drivers of undernutrition described in other LMICs with severe undernutrition burdens, which have not been described in countries in the Sahel. Collectively, we hypothesize that some drivers of undernutrition not reported in Sahelian contexts – individual or linked by linear or non-linear associations - may be explanatory of the phenomenon of persistent undernutrition. If ignored in the region, it makes it challenging to target and assess nutrition interventions, hampering their success.

The Sahelian context presents distinctive characteristics at different demographic, societal, and environment levels, reflected in dimensions such as livelihoods, culture and traditions, health and food systems, environment, and seasonality, and also political stability and conflicts. Although the UNICEF/Young framework accounts for these dimensions, when analysing the considerable number and diversity of drivers and indicators that emerged from the literature, it was hypothesised that, in the Sahelian context, it might be pertinent to revise some of the dimensions, to better aggregate indicators that may be more inter-related and, in so, to illuminate on relevant causes of undernutrition in the region. Sahelian countries show specificities such as i) family traditions and dynamics leading to extreme population growth, ii) under developed food systems (very close to farming systems due to poor or absent linkages to structured markets), iii) [insufficient/not structured] health systems that are not embedded in the socioeconomic/natural environment, iv) harsh agroecological conditions prone to extremes and climate shocks, or v) farming systems characterised by strong seasonality. Hence, two adjustments to the subcategories of the framework were considered worthwhile: adding a complementary dimension in "Immediate drivers" (individual characteristics), and sub-clustering a) "Inadequate social & care environment" into "insufficient health services" and "unhealthy environment", b) "Food and health systems" into "Food systems" and "Health systems", and c) "Environment & seasonality" into "Climate variability and extremes" and "Seasonality".

**Implications**

This study points to the fact that the Sahel region, when it comes to nutrition, receives higher attention from the health research community, confirming previous findings that highlighted the restricted evidence base

of nutrition research in the region. Especially in the less economically developed countries, research is sparse and primarily concentrated on health treatment. This stands as an important limitation in nutrition programming because of the known poverty status of the populations, who rely on farming systems highly vulnerable due to harsh agroecological conditions, resulting in food insecurity and inadequate diets. Urgent action is required to develop solutions that address the roots of nutritional issues, using available resources effectively (currently there are insufficient funds and limited technical capacity to conduct, writing and publishing nutrition research). It might be relevant to address undernutrition drivers in multiple policies and programs across these countries, not only those that are nutrition-specific. Local capacities must be reinforced to allow conducting research addressing the larger drivers of malnutrition, particularly the interlinked effects across long causal pathways. Also, a high heterogeneity in available data between different countries is noticeable, further highlighting the importance of investing in nutrition research in Sahelian countries with fewer available resources. This is important since data on underlying and basic/systemic causes of undernutrition are seldom collected by the DHS or other population surveys conducted by international agencies. This might reflect the need to rethink future studies that rely on data sources beyond population surveys.

By using the “best-fit” framework-synthesis approach to analyse the identified drivers, we propose an adjustment to the framework, to cope with the specific context of the Sahel. Some relevant specificities of the Sahel are not specified in the UNICEF/Young framework. Being a comprehensive framework however, it does not capture contextual and specific features of all settings, such as the unique social and ecological environment of the Sahel and this can be a limitation to the understanding of the local drivers to better target policies and to better design M&E programs. Adding granularity to the graphical representation of the framework can be instrumental to guide specific interventions targeted to key dimensions of undernutrition, leveraging the probability of success in this region.

## Keywords

Anaemia; drivers; framework synthesis; Sahel; stunting; undernutrition; wasting

# 1. Objective of the study

The aim of the Research Study "Drivers of persistently high rates of undernutrition in the Sahel – a comprehensive contextualised research" is to produce evidence to assist decision-makers in addressing the problem of persistent undernutrition in several areas of Sahelian countries. The research study is based on a stepwise approach of three study components. The objective of the first component is to review and discuss the representativeness of the drivers of undernutrition reported in the Sahel. The second component employs machine learning algorithms to assess and expand this study's findings, using available geocoded data on the region, from multiple sources including population surveys and satellite data (seconded component). Finally, a third component contextualises, *in loco*, the main explanatory drivers' candidates and established casual associations with areas of support from the international cooperation.

# 2. Background and Context

Persistent undernutrition, such as wasting and stunting in children under five, or anaemia in children under five and women of reproductive age has been consistently observed in the Sahel and West Africa [12,14]. Findings from nutrition surveys conducted in 2022 highlighted an extremely high prevalence (>15%) of wasting in children under five years in some areas of Burkina Faso, Chad, Mali, and Mauritania and a high prevalence (>10%) in larger areas of Burkina Faso, Mali, Mauritania, Niger, Nigeria, and Chad. Health facility admissions for severe wasting in 2022 increased by 31% as compared to 2021. Likewise, high (>20%) to very high (>30%) prevalences of stunting were observed in Burkina Faso, Guinea, Mali and Mauritania, and Cameroon, Chad, and Niger. Data from the same surveys also showed that The West and Central Africa Region is one of the top three regions worldwide with the highest prevalence of underweight women (10%) and anaemia in adolescent girls and women (49%)[15]. Undernutrition can have immediate effects, such as increased susceptibility to infections and impaired physical and cognitive development, as well as medium-term effects, including stunted growth and delayed sexual maturation. In the long term, undernutrition can lead to chronic health issues like cardiovascular disease, diabetes, and diminished cognitive function [16–19].

Local decision-makers recognise that undernutrition persists in the region despite the significant concentration of regular and sustained nutrition programming supported by national governments and by international humanitarian and development agencies[1]. As such, the identification of the critical drivers explaining the persistence of undernutrition is utmost needed for an appropriate refinement of policies and programmes, in line with the EC's commitment and Action Plan to reduce stunting in children under five by at least 10% of the World Health Assembly goal by 2025[2]. Nevertheless, several challenges are worthy to be acknowledged. First, the development community faces new challenges of uncertain budgets and resource

[1] The assumption on the "high sustained nutrition programming supported by national governments and international humanitarian agencies" was claimed by the decision-makers during the regional workshop, when identifying research needs. The EU has, in fact, assumed strong nutrition commitments with LMIC, and especially in the Sahel, for decades, in the scope of the **EU Action Plan on Nutrition**. Since 2014, the financial effort to supporting "development" has globally surpassed the "humanitarian aid" support. Sahelian countries received 599.77M€ in development Aid Nutrition Disbursements, which is more than half of the total support to all Sub-Saharan countries (1,106.95M€) and more than 1/3 of the global 1,705.22M€ funding of partner countries that prioritised nutrition in their cooperation programs with the EU. Details on budget allocations are available at: https://op.europa.eu/en/publication-detail/-/publication/d370223d-3894-11ed-9c68-01aa75ed71a1/language-en. Also, concerning humanitarian aid to countries of the Sahel and Lake Chad region to support their efforts to achieve peace, security and development, The European Union Emergency Trust Fund for stability and addressing root causes of irregular migration and displaced people in Africa (EUTF for Africa or EUTF) was launched in November 2015. Since then, and until September 2021, the EUTF has committed €2.21 billion to assist projects in the Sahel and Lake Chad region, in a total of 202 operational projects. Additional information available at: https://trust-fund-for-africa.europa.eu/where-we-work/regions-countries/sahel-lake-chad_en

[2] https://knowledge4policy.ec.europa.eu/publication/action-plan-nutrition-reducing-number-stunted-children-under-five-7-million-2025_en

flows in the context of growing responsibility given to national and regional actors, such as regional development banks and governments[20]. The endurance of public interventions often depends on successive governments' political and ideological approaches, aggravating instability. Second, findings from previous research efforts conducted in Africa have already highlighted that Nutrition research has often a restricted evidence base. Especially in the less economically developed countries such as Niger or Chad, research is sparse and primarily concentrated on treatment of health. Urgent action is required to develop solutions that address the roots of nutritional issues, using available resources effectively (insufficient funds and limited technical capacity to carry out, writing and publishing nutrition research)[21].

The Sahel is characterised by extreme climate variability and erratic and seasonal temperatures (above 20ºC and reaching 40-50ºC), exacerbated by climate change. Scattered along vast low-lying arid and semi-arid areas, a large share of the population is organised in pastoralist, agro-pastoralist, and farming communities, whose production systems have evolved to adapt to these harsh agroecological environments. Food systems are fragile and poorly linked to the market. However, among these communities, there is an increasing migration trend to market towns, to diversify their livelihoods due to limited economic opportunities [12]. Most importantly, the region faces long-lasting and ongoing cycles of shocks, crises and political instability, together with one of the world's highest population growth rates. This context sustains rooted poverty that challenges availability and access to quality and diverse foods and to sanitation. The Sahel can be defined according to the geographic coverage or political classifications. For the present study the following countries have been included, combining both approaches: the countries targeted by the Sahel and Lake Chad region of intervention of the EU Trust Fund for Africa (Burkina Faso, Cameroon, Chad, Cote d'Ivoire, Ghana, Guinea, Mali, Mauritania, Niger, Nigeria, Senegal and The Gambia)[3], and the countries located in the semi-arid and arid climate zones, from the Atlantic Ocean to the Red Sea, lying between 12°N and 20°N longitude (Ethiopia, Sudan, Eritrea and Djibouti).[4]

The scientific community has developed frameworks illustrating the drivers of undernutrition, most of which derive from the "UNICEF conceptual framework of undernutrition," first developed in 1990, regularly updated[8,9], and adopted by the World Health Organisation[10]. This framework often guides nutrition programming, as well as monitoring and evaluation (M&E) of interventions. As a universal valid framework however, it does not capture contextual and specific features of all settings, such as the unique social and ecological environment of the Sahel. This can be a limitation to the understanding of the local drivers to better target policies and to better design M&E programmes. An updated version of the framework was designed in 2020 by Young et al. [12]. This update added specific characteristics of acute malnutrition in Africa's drylands, covering countries in the Sahel and West Africa [12], accounting for these phenomena by adding "systemic dimensions" such as livelihood systems, systems of formal and informal institutions, and environment and seasonality (Figure S1). This concern highlights the need to fine-tune for contexts showing distinctive characteristics. [9,10]

# 3. Methods

## 3.1 Type of review

This systematic review is based on the "best-fit" framework-synthesis approach[1,2]. This approach was considered suitable for the purpose of the study since it gathers insights from disciplines from empirical health to social studies and is based on both quantitative and qualitative data, given the paucity of explanations for the persistence of undernutrition in the Sahel[1,2]. Using an a priori framework for data

[3] European Union, available at: https://trust-fund-for-africa.europa.eu/where-we-work/regions-countries/sahel-lake-chad_en

[3] OECD classification, available at: https://www.oecd.org/swac/topics/siccs.htm

analysis, it allows the combination of deductive (framework) and inductive (thematic) approaches, thus facilitating an interpretation contextualised by the UNICEF's comprehensive conceptual framework of undernutrition.

Considering the number and heterogeneity of published studies on undernutrition drivers, and specifically focusing on countries located in the Sahel (whether regarding outcomes, types of reviews, year of publication, etc.), existing evidence was summarised through a systematic review of (under/mal)nutrition-related published narrative and systematic reviews.

## 3.2 Proposed framework

Given the particular focus of this study on the Sahelian region, the framework *Acute malnutrition in Africa's drylands,* developed by Young et al. [12] was the *a priori* framework selected to outline the findings of this systematic review.

## 3.3 Eligibility criteria

The inclusion criteria were based on the following "Population, Intervention, Comparison, Outcomes and Setting (PICOS)" framework categories, expanded with timeframe and language.

***Table 1.*** *Inclusion criteria, based on Population, Intervention, Comparison, Outcomes, Setting (PICOS), Timeframe and Language.*

| | **Detail** |
|---|---|
| **Population** | Children under 5 years, infants less than 6 months and women of reproductive age (15-49 years) |
| **Intervention/Exposure** | Reviews reporting the prevalence of undernutrition and its drivers (excluding those addressing interventions and programmes related to undernutrition). |
| **Comparison** | No comparison groups were considered |
| **Outcome** | Stunting, wasting, anaemia, undernutrition |
| **Setting** | Sahel and individual countries (Burkina Faso, Cameroon, Chad, Cote d'Ivoire, Ghana, Guinea, Mali, Mauritania, Niger, Nigeria, Senegal, The Gambia, Ethiopia, Sudan, Eritrea and Djibouti) |
| **Timeframe** | Studies published until 31 December 2022 |
| **Language** | English, French |

## 3.4 Search strategy

1) Structured electronic search on the following databases: Medline, Clarivate Web of Science Core Collection, Cochrane Library, Cumulative Index to Nursing and Allied Health Literature (CINAHL) (CINAHL), International Bibliography of Social Science (IBSS), PsycINFO and African Journals Online (Table 2).
2) "Grey literature", through searching relevant organisations or development agencies' websites, namely: 3ie impact assessment, United Nations Children's Fund (UNICEF), United Nations Development Program (UNDP), Food and Agriculture Organisation of the United Nations (FAO), World Food Program (WFP), WHO, World Bank, African Development Bank, Save the Children, Action Against Hunger, Nutrition International, Global Alliance for Improved Nutrition (GAIN), International Food and Policy Research Institute (IFPRI), Nutrition Innovation Lab / Feed the Future, Bill and Melinda Gates Foundation.
3) Forward and backward citation tracking of all the eligible publications.

***Table 2**. Search strategy approach.*

| Database: Medline/ PubMed | |
|---|---|
| **Search no.** | **Syntax** |
| **# 1** | baby OR toddler OR babies OR paediatr* OR neonat* OR newborn* OR infant* OR "under 5*" OR "under five*" OR "under-five*" OR "child, preschool" OR preschool* OR girl OR boy OR "women of reproductive age" OR women OR bébé OR bambin OR bébés OR pédiatre* OR nouveau-né* OR nourrisson* OR "moins de 5 ans*" OR "moins de cinq ans*" OR "moins de cinq ans*" OR enfant, préscolaire OU préscolaire* OR fille OR garçon OR "femme en âge de procréer" OR "les femmes" [MeSH] |
| **# 2** | "height for age" OR "length for age" OR "weight for height" OR "weight for length" OR "weight for age" OR "growth disorder" OR "growth failure" OR "growth retardation" OR "short stature" OR wasting OR wast* OR stunting OR stunt* OR MUAC OR "middle-upper arm circumference" OR "skinfold thickness" OR thin OR emaciation OR emaciat* OR "body mass index" OR BMI OR malnutrition OR Malnutr* OR malnourish* OR "acute malnutrition" OR "chronic malnutrition" OR MAM OR "moderate acute malnutrition" OR SAM OR "severe acute malnutrition" OR GAM OR "global acute malnutrition" OR "child malnutrition" OR kwashiorkor OR undernutrition OR undernutr* OR underweight OR undernourish* OR underweight OR "nutritional status" OR "chronic hunger" OR "dietary deficiency" OR starvation OR marasm* OR "micronutrient deficiency" OR "iron deficiency" OR "iron deficiency anaemia" OR Anaemia OR "taille pour âge" OR "longueur pour âge" OR "poids pour taille" OR "poids pour taille" OR "poids pour âge" OR "trouble de croissance" OR "retard de croissance" OR "retard de croissance" OR "petite taille" OR émaciation OR émaciation* OR retard de croissance* OR "épaisseur du pli cutané" OR mince maciation OR maciation* OR "indice de masse corporelle" OR malnutrition OR malnutrition* OR "aiguë malnutrition" OR "malnutrition chronique" OR "malnutrition aiguë modérée" OR "malnutrition aiguë sévère" OR "malnutrition aiguë globale" OR "malnutrition infantile" OR kwashiorkor OR dénutrition OR dénutrition* OR "insuffisance pondérale" OR sous-alimentation* OR "insuffisance pondérale" OR "état nutritionnel" OR "faim chronique" OR "carence alimentaire" OR famine OR marasme* OR "carence en micronutriments" OR "carence en fer" OR "anémie ferriprive" OR Anémie [MeSH] |
| **# 3** | Sahel OR "Burkina Faso" OR Burkinabé OR Cameroon OR Cameroons OR Chad OR "Cote d'Ivoire" OR Djibouti OR Ethiopia OR Eritrea OR "Ivory Coast" OR Ivorian OR Gambia OR Gambian OR Ghana OR Ghanaian OR Guinea OR Guinée OR Guinean OR Mali OR Malian OR Mauritania OR Mauritanian OR Niger OR Nigerien OR Nigeria OR Nigerian OR Senegal OR Senegalese OR Sudan OR "West Africa*" OR "Africa, Western" OR Cameroun OR Cameroun OR Tchad OR "Côte d'Ivoire" OR "Côte d'Ivoire" OR Éthiopie OR Érythrée OR Ivoirien OR Gambie OR Gambien OR Ghana OR Ghanéen OR Guinée OR Guinée OR Guinéen OR Mali OR Malien OR Mauritanie OR Mauritanien OR Niger OR Nigérien OR Nigéria OR Nigérian OR Sénégal OR Sénégalais OR Soudan OU "Afrique de l'Ouest*" OR "Afrique de l'ouest" [MeSH] |
| **# 4** | Caus* OR Factor* OR determinant* OR correlat* OR "risk factor" OR "factor*" multifactorial caus* OR priorit* OR "polic*" OR "program*" OR "intervention*" OR "predictor*" OR "initiativ*" OR "strateg*" OR "trend*" OR "longitudinal" OR "reduc*" OR "trajector*" OR "chang*" OR "declin*" OR Cause* OR Facteur* OR déterminant* OR corrélat* OR "facteur de risque" OR "facteur*" cause multifactorielle* OR priorité* OR "polic*" OR "programme*" OR "intervention*" OR "prédicteur*" OR "initiativ *"[MeSH] |
| **# 5** | #1 AND #2 |
| **# 6** | #1 AND #2 AND #3 |
| **#7** | #1 AND #2 AND #3 AND #4 |
| **#8** | #7 and filter: Language filter: English and French |
| **#9** | #8 and filter: Review, systematic reviews (SR) and meta-analysis |

## 3.5 Screening and study selection

Studies yielded in the search were imported to Microsoft Excel spreadsheets into a single database and duplicates were removed manually. As such, a total of 1408 publications were screened through title and abstract, of which 1264 were excluded according to the eligibility criteria (Figure 1). After this initial selection of 144 articles, full texts of studies were reviewed for final inclusion. This process was undertaken independently by two researchers (GA and LG) and subsequently discussed for consensus.

At the stage of eligibility, 100 studies were excluded based on full-text assessment, namely those: not providing evidence on the relationship between potential drivers and the study outcomes or not reporting data on undernutrition drivers; intervention studies; not reporting on the outcomes of interest; not eligible types of publication or types of studies; duplicated publications. As such, 44 articles were included in the present review. Afterwards, 28 additional publications were added to the pool of studies, through backward and forward citation tracking (n=14), hand-searches of grey literature (n=10) and an update of the search in the scientific databases up to May 2023 (n=4). A total of 72 publications were selected as full text and data was extracted. From these, 60 covered drivers of undernutrition only in children, seven covered drivers of anaemia only in women of reproductive age, and five covered undernutrition drivers in both populations. Detailed information is depicted in Figure 1.

## 3.6 Data extraction, synthesis and analysis

The data extracted included authors, year of publication, language, study setting, aim/objectives, type of publication, type of study, undernutrition outcome(s), population and the drivers identified.

Framework synthesis was conducted through the extraction of information on the drivers of undernutrition in a stepwise process:

1) Information was first extracted in free text form.
   - Identified drivers were grouped according to the acute malnutrition in Africa's drylands framework dimensions of immediate, underlying and basic/systemic causes of malnutrition (Figure S1). Orphan categories captured in literature dedicated to Sahelian countries were documented and the process of definition of their taxonomies was mainly guided by concepts selected based on three analytical frameworks: i) Organisation for Economic Cooperation and Development (OECD) (1996), ii) Scoones (1998), and iii) High Level Panel of Experts (HLPE) (2017), and/or indicators used in the Sustainable Development Goals outline, and the Food Systems Dashboard (Fanzo et al., 2020), as well as the proposals put forward by Abreu and Mesias (2020), Bryden (2002), and Kageyama (2004).

Additionally, a descriptive quantitative analysis was conducted, providing absolute and relative frequencies of characteristics of the eligible publications (publication type, type of literature review, language, study setting and undernutrition outcomes) and all categories and dimensions of undernutrition drivers identified.

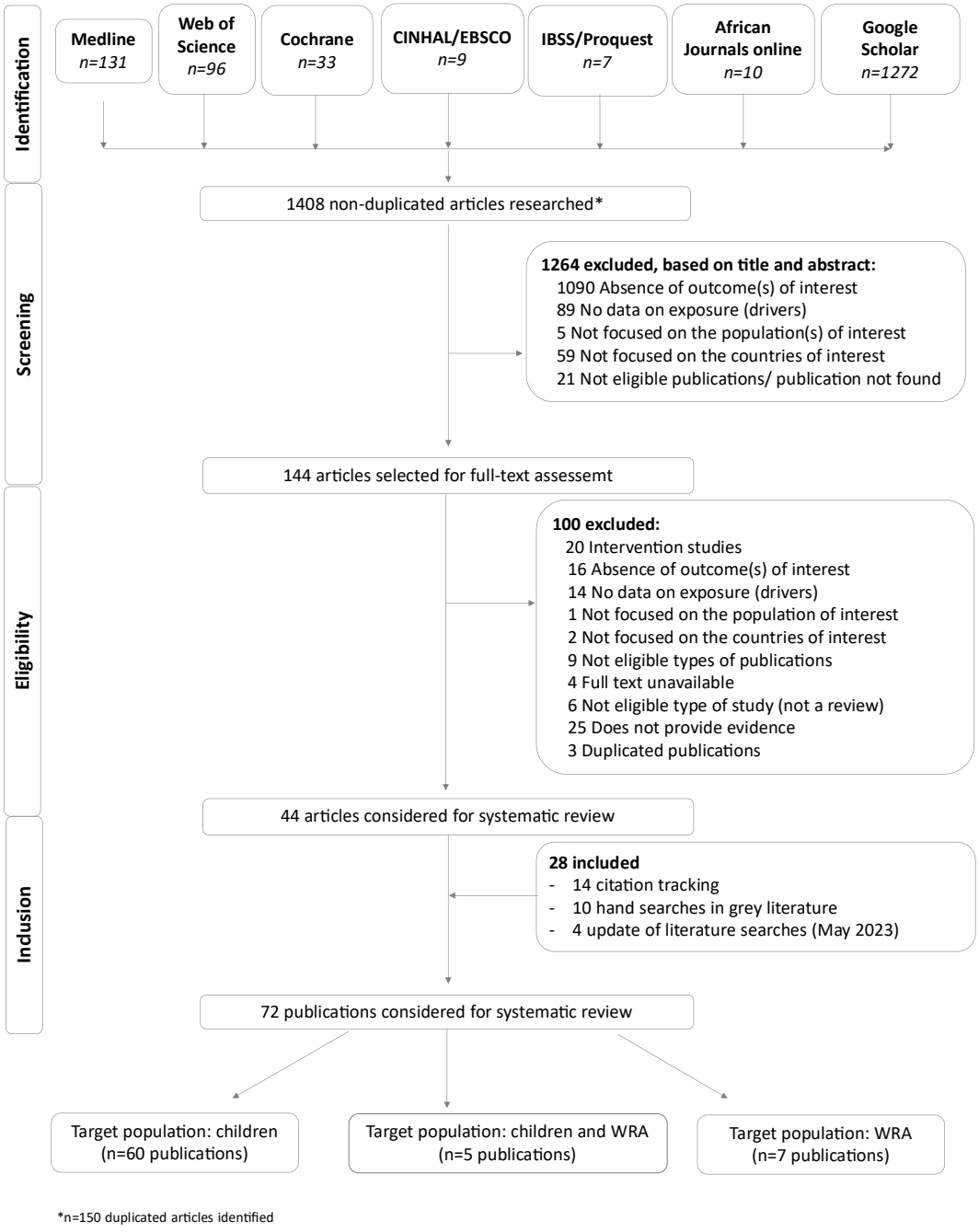



***Figure 1.*** *Flowchart of search results. WRA: Women of Reproductive Age.*

# 4. Findings

## 4.1 Characteristics of included publications

A total of 72 publications identifying drivers of undernutrition in at least one country in the Sahel were included in this study. Most publications were scientific papers (86.1%) and written in English (98.6%). About two-thirds of the literature reviews were systematic (65.3%) and the remaining were narrative reviews (34.7%). Only nine publications (12.5%) were solely focused on the region, which suggested limited attention given by the health/nutrition research community to the Sahel as a geo-socio-economic region. Due to this evidence, the scope of the selected publications was enlarged to include studies from LMICs, including at least one country from the Sahel.

Focusing on publications identifying undernutrition drivers only among children, stunting was the widest reported undernutrition outcome (70.0%), followed by wasting (30.0%). "Undernutrition," defined *sensu lato,* was a common outcome reported in 38.3% of the studies (Table 3).

Among the full set of publications, the countries for which data was most frequently available were Ethiopia (n=52), Ghana (n=35), Nigeria (n=28) and Burkina Faso (n=6). Guinea (n=10), Chad (n=9), Côte d'Ivoire (n=8) and Mauritania (n=4) were the countries from which data on undernutrition drivers were less frequently available (Figure 2).

***Table 3.*** *Characteristics of all included publications (n=72) and of publications reporting drivers of children undernutrition (n=60).*

| | All publications (n=72) | | Publications focused on children (n=60) | |
|---|---|---|---|---|
| | n | % | n | % |
| **Publication type** | | | | |
| Scientific paper | 62 | 86.1 | 51 | 85.0 |
| Technical/discussion paper | 5 | 6.9 | 4 | 6.7 |
| Technical report/publication | 4 | 5.6 | 4 | 6.7 |
| Book chapter | 1 | 1.4 | 1 | 1.7 |
| **Language** | | | | |
| English | 71 | 98.6 | 59 | 98.3 |
| French | 1 | 1.4 | 1 | 1.7 |
| **Type of literature review** | | | | |
| Systematic Review | 47 | 65.3 | 38 | 63.3 |
| Narrative review | 25 | 34.7 | 22 | 36.7 |
| **Study setting** | | | | |
| Only countries in the Sahel | 9 | 12.5 | 8 | 13.3 |
| LMIC, including in the Sahel | 63 | 87.5 | 52 | 86.7 |
| **Outcome*** | | | | |
| Stunting | - | - | 42 | 70.0 |
| Wasting | - | - | 18 | 30.0 |
| Anaemia | 21 | 29.2 | 9 | 15.0 |
| Undernutrition** | - | - | 23 | 38.3 |

* The sum of all the categories is > 60, due to the fact that a given eligible publication could report more than one outcome.

** Undernutrition, as defined by the respective authors.

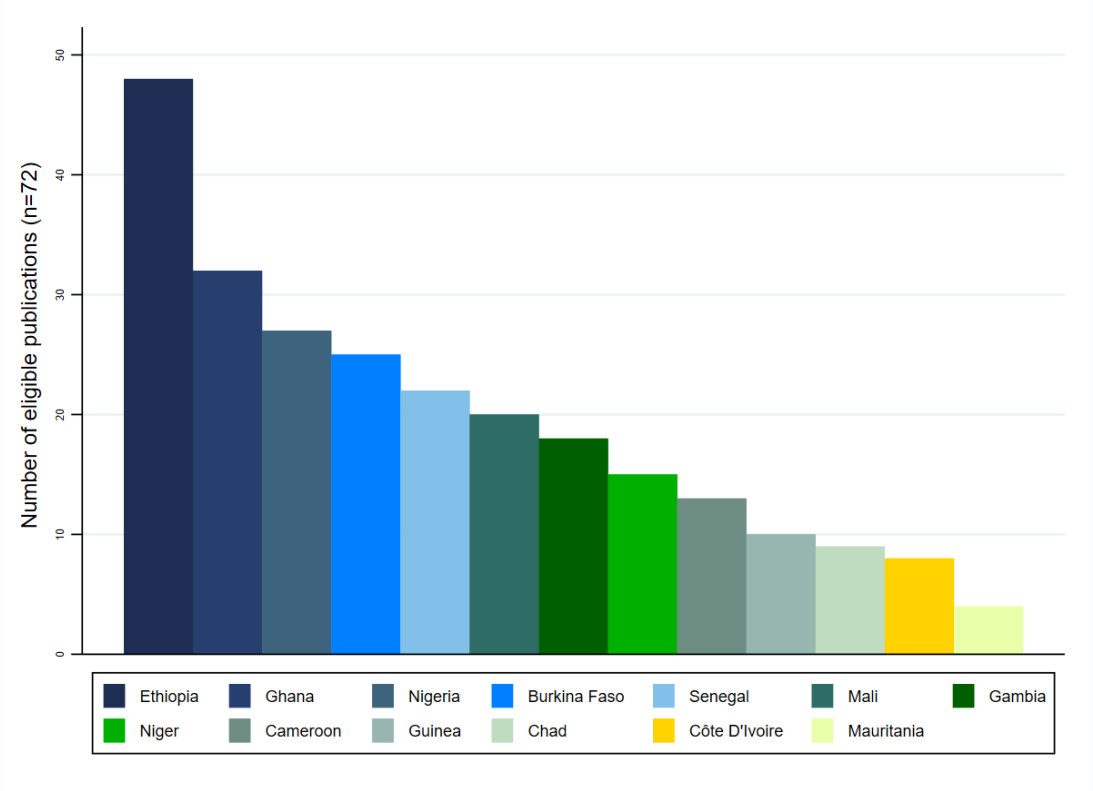



***Figure 2.*** *Number of eligible publications reporting drivers of undernutrition among children and women of reproductive age in each of the Sahelian countries (n=72).*

## 4.2 Reported drivers of undernutrition

### 4.2.1 Framework analysis: categorisation under the UNICEF/Young undernutrition framework

During the process of categorising identified drivers from the literature using the best-fit approach, two adjustments to the subcategories of the framework were considered worthwhile: i) adding a complementary dimension in "Immediate drivers" (individual characteristics) and ii) sub-clustering the dimensions of "Underlying drivers" and "Basic/ systemic drivers"[5].

The frequency of publications reporting drivers of each of the major undernutrition causes (immediate, underlying and basic/systemic) was, overall, similar (Figure 3A). From the whole sample of publications (n=72), 65.3% identified immediate drivers, followed by 62.5% identifying both underlying and basic/systemic drivers. The exception was found in the studies whose outcome was wasting among children (n=18), for which the proportion of publications mentioning both underlying and basic/systemic drivers was high (83.3%), contrasting with immediate drivers (27.8%).

Concerning the dimensions of immediate undernutrition drivers (Figure 3B), "Disease" showed the highest frequency for all publications, varying from 47.6% (anaemia among children and women of reproductive age) to 66.7% (wasting among children 66.7%). Concerning underlying undernutrition drivers, "insufficient health services and unhealthy environment" was the dimension with the highest frequency among studies reporting on all outcomes, varying from 45.8% (undernutrition among children and WRA) to 72.2% (wasting among children) (Figure 3C). "Livelihood systems" was the basic/systematic dimension mostly reported, varying from 41.7% (undernutrition among children and WRA) to 77.8% (wasting among children) (Figure 3D).

[5] The implications are discussed in sub-section 3.3 (Implications for indicators' use to assist nutrition programming in the Sahel) and illustrated in Figure 4, below. While the later adjustment is not important for the current section, the former is considered in the categorisation.

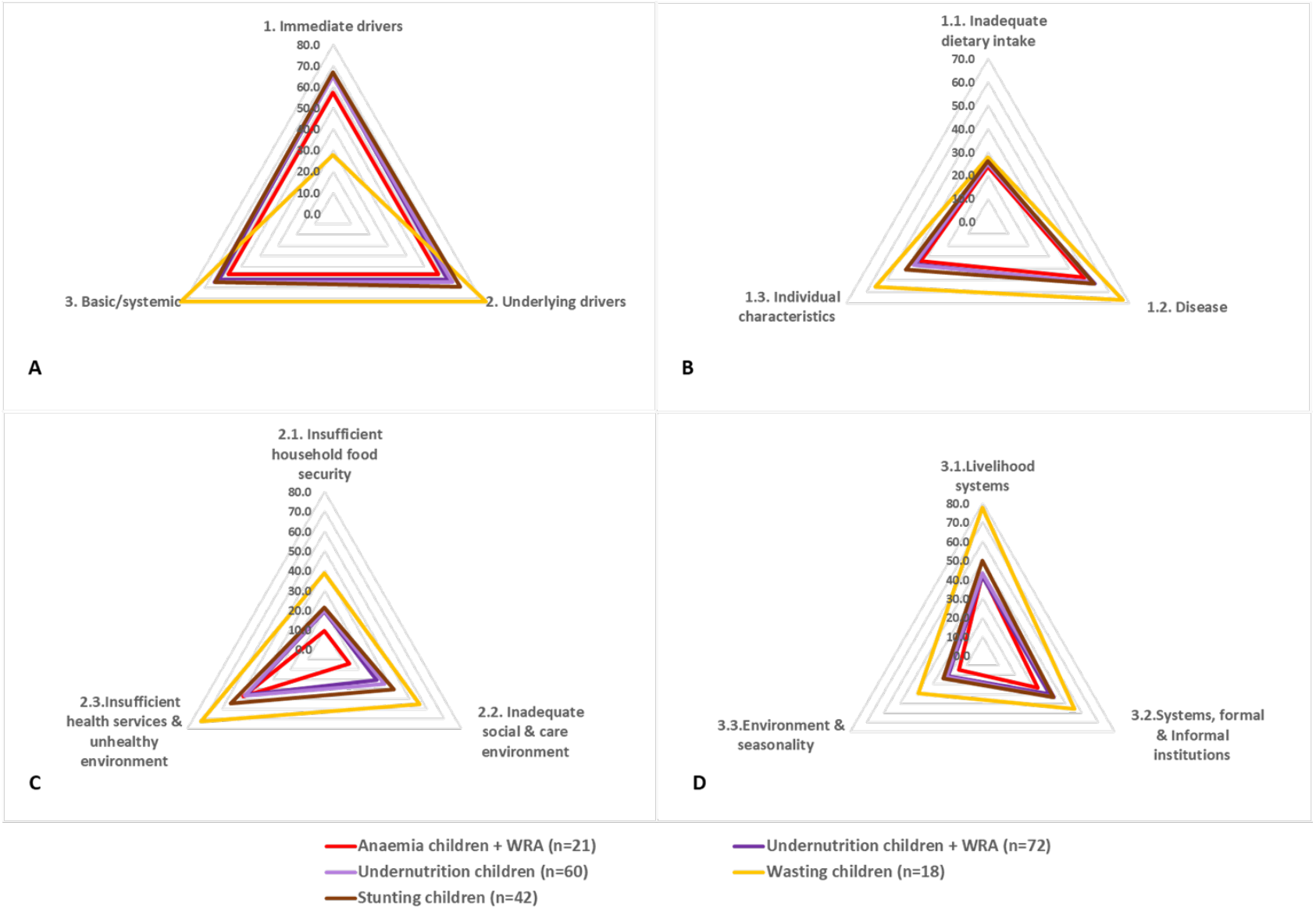



***Figure 3.*** *Frequency of reported undernutrition driver categories, by outcome. A: Main categories; B: Immediate drivers; C: Underlying drivers; D: Basic/ systemic drivers*

Interestingly, Figure 3 shows a low prevalence of publications reporting on dimensions of undernutrition drivers such as dietary intake, household food security and environment & seasonality, and a higher prevalence of publications focusing on disease, health & care environments, and context of formal and informal institutions[1] as explanatory dimensions of undernutrition drivers, as defined by Young et al[12].

### 4.2.2 Organisation and contextualisation of reported drivers of undernutrition in the Sahel

Table 4 lists each of the 76 individual drivers of undernutrition identified in Sahelian countries, as captured in the systematic review, as well as its citation frequency, associated nutrition outcome and country(ies) in which they were reported.

***Table 4.*** *List and citation frequency of identified drivers of undernutrition, organised by dimensions and categories, and contextualised in the Sahel (according to outcomes and countries where each driver has been described) (n=72 publications).*

| Drivers of Undernutrition grouped by Dimensions / Categories | Contextualisation in the Sahel | | |
|---|---|---|---|
| | Countries | Outcomes | No. citations |
| **1.IMMEDIATE:** | | | |
| **1.1.Inadequate dietary intake** | | | |
| **1.1.1.Child** | | | |
| Poor diet quality/ unhealthy diet/ Inadequate dietary intake [22–29] | SAHEL; ETH | ● ● | 2 |
| Low dietary diversity [17,23,25–30] | BF; ETH; GHA; MAL; NGA | ● ● | 7* |
| Minimum acceptable diet [26,30,31] | BF; CHA; MAL; MAU; NIG; NGA | ● | 6 |
| Low meal frequency (≤3x/day)/ Minimum Meal Frequency (MMF) [32][31] | ETH | ● | 1 |
| **1.1.2.Maternal** | | | |
| Poor diet quality (during pregnancy)[25,33–35] | ETH | ● ● ▲ | 3 |
| **1.2.Disease** | | | |
| **1.2.1.Child** | | | |
| Mortality [23] | ETH | ● | 1 |
| Communicable diseases [23,28,36–40]/ Water- and vector-borne diseases [41] | GAMB; | ● ● ● ● | 5 |
| Infection [41–44] / Recurrent infections [25]/ Parasitic infection (e.g., digestive and urinary parasitosis; intestinal parasites) [33][45] | CAM, CI | ● ▲ | 1 |
| Malaria [21,28,31,32,41,42][27] / High malaria prevalence [34] | SAHEL ; CAM ; CI ; ETH ; GAMB ; MAL, NIG | ● ● ● ● | 7* |
| Poor gut health/ Enteric Pathogen Infections /Environmental Enteric Dysfunction [22,27,44,46–48]/ Disrupted gut microbiota [27,49]/ Intestinal inflammation [50]/ Gut permeability [27]/ Other digestive diseases [33] | GAMB; MAL | ● ● | 4 |
| Recent illness (e.g., fever in last 2 weeks, acute respiratory infection – ARI, high prevalence of ARI, Diarrhoea, high diarrhoea prevalence) [21,24–27,29,32–34,36,40,43,45,48,49] | CI; ETH; GAMB; MAL; NGA; | ● ● | 7* |
| Undernutrition (e.g., nutritional status, stunting, wasting, anaemia, underweight) [22,28,32,36,40,48,51–53] | BF; ETH; GAMB; GHA; NIG; NGA; SEN | ● ● ● ● | 9* |
| **1.2.2.Maternal** | | | |
| Infection during pregnancy – systemic [25], intra-uterine [25], malaria [54]/ Infection burden [55] | MAL | ▲ | 1 |

[1] According to Young, 2021[12]: institutions determine how individuals, families and communities access the critical resources needed to fulfil their food, health, and care needs. Examples of informal institutions may include markets and the land tenure regime.

| Drivers of Undernutrition grouped by Dimensions / Categories | Contextualisation in the Sahel | | |
|---|---|---|---|
| | Countries | Outcomes | No. citations |
| Mental illness during pregnancy [56]/ Antenatal depression [57] | ETH; GHA | ● | 2 |
| Nutritional status: low BMI [28,32–34,48,54,55,58]; high BMI [27]/ Nutrition [52,59] (during pregnancy [27]) /MUAC <23 cm [35] | ETH; GHA; GUI; NGA; SEN | ● ● ● ▲ | 9* |
| Micronutrient deficiencies (pregnancy) [33] | ETH | ● | 1 |
| **1.3.Biological/Individual characteristics** | | | |
| **1.3.1.Child** | | | |
| Sex (male) [23,24,28–30,32–34,41,46,48,58–63] | BF; CAM; CI; ETH; GAMB; GHA; GUI; MAL; NGA; SEN | ● ● ● ● ● | 17* |
| Age [23,24,28,29,32,34,41,58,60–63] | BF; CAM; ETH; GHA; MAL; NGA; SEN | ● ● ● ● | 15* |
| Birth order (i.e., having more siblings) [29,32,34,48,61] | NGA | ● | 1 |
| Type of birth (multiple) [28,29,32,34,54,64] | ETH; GHA; NGA | ● ● | 3 |
| Low birthweight [28,32,34,41,52,54,61,65] | ETH; GHA, NGA | ● ● | 7 |
| Small for gestational age (SGA) [28,41,52,66]/ Birth size [31,32]/ Perceived child's birth size [32] | ETH | ● | 1 |
| **1.3.2.Maternal/caregiver** | | | |
| Age [28,29,32,34,54,55,58] | ETH; GHA; NGA; | ● ● ● ● | 5 |
| Low parity/short interpregnancy intervals [29,32,34,35,52,54,55,59,61,67] | ETH; MAL; NGA; SEN | ● ● ▲ ▲ | 7 |
| Height (short) [25,27,29,31,32,34,43,48,68] | ETH; GHA | ● ● | 4 |
| **2.UNDERLYING:** | | | |
| **2.1.Insufficient household food security** | | | |
| Food insecurity (household, child's) [23,29,30,37,54,59,60,69–73]/ High levels of acute food insecurity [26] | BF; CAM; CHA; ETH; GHA; MAL; NIG; NGA | ● ● ● ● | 11* |
| Household agricultural/livestock production [22,32,34,59,74] | ETH | ● ● | |
| **2.2.Inadequate social & care environment** | | | |
| **2.2.1.Inadequate care environment** | | | |
| Poor breastfeeding practices (*e.g.,* no breastfeeding; non-exclusive until 6 months; duration)[22,23,26–28,32–34,41,48,54,64,75] | SAHEL; ETH; GHA; NGA | ● ● ● ● ▲ | 9* |
| Poor or inadequate complementary feeding practices (e.g., early weaning; starting complementary feeding after 6 or 12months) [22,25,28,31,34,48,49,54,74,75] | ETH | ● | 1 |
| Family care structure/ child displacement from the family/unaccompanied/ orphaned [23,24,26]/ child abandonment [76]/paternal orphan [32] | NGA | ● | 1 |
| Stress of displacement [42] | CHA | ● ▲ | 1 |
| **2.3.Insufficient health services & unhealthy environment** | | | |
| **2.3.1.Insufficient health services** | | | |
| Access to health centres/community resources/health facilities [29,48] | SAHEL; BF; CHA; CI; GAMB; GHA; GUI; MAU; NIG; SEN | ● | 3 |

| Drivers of Undernutrition grouped by Dimensions / Categories | Contextualisation in the Sahel | | |
|---|---|---|---|
| | Countries | Outcomes | No. citations |
| Access to antenatal/prenatal care/ Antenatal visits/Antenatal care 4+ visits [22,29,34,35,54,55,59,60,67,70,74] | ETH; SEN | | 7* |
| Access to/quality of maternal care [59,74] | ETH; SEN | | 1 |
| Access to family planning/reproductive health [59,60,70] / contraceptive use [28,54,55,59] | ETH | | 1 |
| Access to deworming in the last 6 months/Deworming status [32,60] | CAM; ETH; GUI; SEN | | 2 |
| Immunisation (status) [22,28,60]/ (Ever had) vaccination [32] | ETH | | 2 |
| Health-seeking behaviours [22]/ Reduced care seeking [70]/ mother health-seeking [32] | NGA | | 1 |
| Maternal supplementation (pregnancy) [35] | ETH | | 1 |
| Has health insurance/ Maternal health insurance [32] | GHA | | 1 |
| Place of birth delivery [32,54,61]/ Access to professional or skilled birth [29,54,55] | ETH; SEN | | 2 |
| **2.3.2.Unhealthy environment** | | | |
| Poor WASH conditions (e.g., hand washing, presence of soap and water near latrine; hygienic environmental settings; lack of adequate waste disposal in the community, household hygienic conditions; dirty floors) [22,23,26,41,46–48,59,60] | MAL | | 1 |
| Poor access to (safe) sanitation [26–28,30,32,34,47,51,54,55,69,70] | SAHEL; ETH; GHA; GUI; | | 5 |
| Water insecurity (low availability, accessibility, use, reliability) [77] / Low or poor access to clean water [26–28,30,32,34,38,39,45,55,69,70] | SAHEL; ETH; GAMB; GHA; SEN | | 5 |
| Open defecation [34,47,48,54,59] | ETH | | 3 |
| Dwelling quality [31,34]/ Family housing quality (type of dwelling, availability of a safe water supply, adequacy of sanitation, and rubbish collection) [48]/ Lack of basic infrastructure (water, sanitation) [48,58] | ETH | | 2 |
| Exposure to indoor smoke because of low quality cooking fuel [31]/ Poor quality cooking fuels [32,47]/ Household air pollution (from solid fuel use)/ Type of household fuel use for cooking [34,78] | ETH | | 3 |
| Exposure to outdoor air pollution/biomass smoke/ polycyclic aromatic hydrocarbons (PAHs) [56,74,79] | GHA | | 1 |
| Exposure to foodborne mycotoxins [47]/ aflatoxins [74,80,81]/ intestinal parasites [47] | GAMB | | 1 |
| **3.BASIC/SYSTEMIC:** | | | |
| **3.1.Livelihood systems** | | | |
| **3.1.1.Livelihood resources, strategies & goals** | | | |
| Household /maternal wealth/wealth index/ increased poverty [27,29,32,34,55,56,74] | BF; CHA; ETH; GHA; MAL; MAU; NGA; NIG | | 9* |
| Ownership of radio [32]/ Ownership of tv [32]/ land owned [32]/ Use of internet facility [32] | ETH | | 1 |
| Low household education [22,52,55]/maternal education [28,29,31,32,34,35,41,54,58–62]/ paternal education [29,54]/ Parental literacy rate [54] | CAM; ETH; GAM; GHA; NGA; SEN; | | 15* |
| Occupation [54,55] (maternal [32,58]; paternal[32])/ Unemployment [34,41] | ETH | | 2 |
| Family size [29,31,34,35,58,60,62]/ Number of children <5 years old in the household [31,32]/ number of dependent children [32]/ dependency ratio [31]/ Household crowding [54] | CAM; ETH; GAMB; GHA; GUI; SEN | | 7* |
| Loss of family providers [42] | ETH | | 1 |
| Sex of household head [31,32]/ Single parenting [32]/ Maternal marital status [32] | ETH | | 1 |
| Human capital [82] | SAHEL | | 1 |
| Region/province/place of residence /urban-rural residence [24,28,29,32,35,54–56,58–62,68] | IC; CAM; ETH; GAMB; GHA; GUI; NGA; SEN | | 9* |
| **3.2.Systems, formal & Informal institutions** | | | |

| Drivers of Undernutrition grouped by Dimensions / Categories | Contextualisation in the Sahel | | |
|---|---|---|---|
| | Countries | Outcomes | No. citations |
| **3.2.1.Governance & Political Economy** | | | |
| Political economy [24,54,55] | CAM; GHA | ●●● | 2 |
| Poverty [22,23,30,41,83] | NGA | ● | 1 |
| Poor education [83]/ Low illiteracy rate [32,59]/ Female education [29,69] | NGA | ● | 1 |
| Migration [56]/ Mountainous population migration [54]/ Massive population displacements [26,30] | BF; CAM; CHA; MAL; NGA; NIG | ▲● | 1 |
| Urbanisation [22,40,41] | SEN | ● | 1 |
| Civil Insecurity [23,26,39]/ Violence [82] | SAHEL; BF; CAM; CHA; MAL; NGA; NIG | ▲● | 3 |
| Emergency preparedness [23] | BF; ETH; GAMB; GHA; MAL; NGA; NIG | ● | 1 |
| Human-induced disasters[23]: Conflicts/Armed conflicts/civil or communal conflicts/protracted armed conflicts [23,26,30,42,48,82,84,85]/ place of birth near or born during a conflict [29,47] / exposure to conflict (days or months and/or severity/typology) [29,85] | BF; CAM; CHA; ETH; MAL; MAU; NGA; NIG | ●● ▲● | 6 |
| Other disasters – Epidemics or Pandemics: Mortality epidemics [82]/ Measles epidemic [39]/ Coronavirus Disease 2019 (COVID-19) pandemic [26,70] | SAHEL | ● | **1** |
| **3.2.2.Food & Health systems** | | | |
| **3.2.2.1.Food Systems** | | | |
| Household access to irrigation [38]/ Low water availability [56] | GAMB | ●● | 1 |
| Disruptions/limited/interrupted food supply chains [23,26,70] | BF; CAM; CHA; MAL; NGA; NIG | ▲● | 1 |
| Foreign economic embargos / "Food as a weapon of war" [42] | ETH | ● | 1 |
| **3.2.2.2.Health Systems** | | | |
| National Nutrition policy [22,24,54] | ETH | ●●● | 1 |
| Low health system quality [23,28,70]/ Health system degradation [23]/ Low surge capacity [23] | ETH; NGA | ● | 2 |
| **3.2.3.Gender, cultural & social norms** | | | |
| Gender equity/empowerment [55,69]/ Women's autonomy [48,86]/ empowerment [59,83,87,88]/ Family empowerment: Mothers' decision making in the household, education, and environment [89]/ Women's control of their living environment / decision-making ability [41,86] | ETH, MAL | ●● ▲ | 2 |
| Cultural norms and behaviour [55]/ Health & food beliefs/misconceptions/cultural practices [22,23]/ Food cultural acceptability/taboos [23,26] | SAHEL; NGA | ●● | 2 |
| Religion [23,32] | ETH | ●● | 3 |
| **3.3.Environment & seasonality** | | | |
| **3.3.1Climate Variability & Extremes** | | | |
| Natural disasters [23,24,70]: Flooding [37,48,56,82,90]; Droughts [26,29,37,48,56,82,91]; Storms [56]; Heatwaves/extreme temperatures/ higher temperatures [29,56,90]; aridity [82]; rainfall levels variability [37,56,82]/ excessive rainfall [29,37]/ low amounts of precipitation [56]/ lack of precipitation over time [56]; Pests [41,82] | SAHEL; CAM; ETH; GHA | ● ●▲ | 6 |
| **3.3.2.Seasonality** | | | |
| Seasonality [22,30,48,52,67,80,90]/ Wet season [38]/ Growing season [82] | BF; CHA; MAL; MAU; NGA; NIG | ●●● ▲ | 5 |

***Legend:***
***Countries:*** *BF– Burkina Faso, CAM – Cameroon, CHA – Chad' CI– Côte d'Ivoire, ETH– Ethiopia, GAMB– Gambia, GHA– Ghana, GUI– Guinea, MAL– Mali, MAU– Mauritania, NG– Niger, NGA– Nigeria, SEN – Senegal*
***Outcomes:*** ***Stunting*** ***Wasting*** ***Underweight*** ***Undernutrition*** ***Malnutrition*** ***Anaemia***
***Population:*** ○ ***Children*** △***Women of reproductive age***
***:*** *Drivers reported by ≥10'% of the publications (n=72).*

Table 5 summarises the degree of association of Sahelian countries, nutrition outcomes and publications reporting the identified drivers, per level of cause (immediate, underlying and basic/systemic). Despite the similar number of drivers in each level, the results show a lower number of countries, outcomes and publications to which "underlying drivers" are reported. Noticeable, the number of publications reporting "immediate drivers" was significantly higher than the number of publications reporting "underlying" and "basic/systemic drivers."

***Table 5.*** *Summary of the citation frequency of Sahelian countries, nutrition outcomes and publications with respect to the number of identified drivers of undernutrition (n=72 publications).*

| | Immediate drivers | Underlying drivers | Basic/Systemic drivers |
|---|---|---|---|
| **Drivers** | 25 | 23 | 28 |
| No. countries per driver | 3.32 | 2.43 | 3.32 |
| No. outcomes per driver | 2.28 | 1.87 | 2.36 |
| No. publications per driver | **5.04** | 2.83 | 3.14 |

Details and association between each of the drivers and undernutrition outcomes are clarified henceforth:

## 1. Immediate drivers:

### 1.1 Inadequate dietary intake

#### 1.1.1 Child

- **Poor diet quality/ unhealthy diet/ Inadequate dietary intake:**
  - In Ethiopia, low consumption of flesh foods in infants was identified as a risk factor for anaemia in this population group[33] School-aged children who had the habit of consuming tea were at lower risk of stunting. Those who consumed alcohol were at higher risk of wasting[28].
  - In the Sahel, poor food consumption patterns, lack of access to healthy diets, inadequate child-feeding practices and low breastfeeding rates, underlined by cultural taboos relating to food choices, leads to malnutrition among children[26].
- **Low dietary diversity/MDD:**
  - In Burkina Faso, the inverse association between dietary diversity and linear growth was stronger in children younger than 36 months[71].
  - In Ethiopia, dietary diversity was inversely associated with the risk of stunting, among children aged 0-59 months[32,71] and among school-aged children[28].
  - In Ethiopia, Ghana and Nigeria, a possible association between low dietary diversity and stunting among infants and children aged < 5 years was identified[92].
  - In Mali, a doubled risk of stunting was observed in urban children with low dietary diversity score[71].
- **Minimum acceptable diet:**
  - In Burkina Faso, Chad, Mali, Mauritania, Niger and Nigeria, countries with a high prevalence of acute undernutrition among under-five children, the proportion of children aged 6–23 months who are fed the minimum acceptable diet is extremely low, varying from 14% (Niger) – 18% (Nigeria)[26,30].
- **Low meal frequency:**
  - In Ethiopia, children with a high meal frequency (i.e., three meals per day) were less likely to be stunted than their peers[31].

1.1.2. Maternal

- **Poor diet quality:**

  - In Ethiopia, low consumption of flesh foods in mothers was considered a risk factor for anaemia in infants[33]. Poor maternal diet was associated with a higher risk of malnutrition among children[34]. Low dietary diversity during pregnancy was associated with a higher risk of maternal anaemia[35].

### 1.2. Disease

1.2.1 Child

- **Mortality:**

  - In Southern Ethiopia, a research study conducted in the 1990's during a famine in the region concluded that increased childhood mortality, specifically during a disaster (due to increased nutritional needs that cannot be fully met by general food allowances and rations) was also associated with increased undernutrition among children [23].

- **Environmental Enteric Dysfunction (EED)/ Poor gut health/Enteric Pathogen Infections/ Environmental Enteric Dysfunction/ Disrupted gut microbiota/ Intestinal inflammation/Gut permeability/ Other digestive diseases :**

  - In the Gambia, a study on Gambian children found an association between poor intestinal absorption and stunting[27,48].

  - In Mali, a study suggested that WASH interventions may result in decreased undernutrition through an effect on decreasing Environmental Enteric Dysfunction[46].

- **Parasitic infection:**

  - In Cameroon and Côte d'Ivoire, the prevalence of anaemia is higher in populations at risk of inflammation and linked to infections (malaria, parasitosis, including schistosomiasis) and hygiene conditions[33].

- **Malaria'**

  - In Côte d'Ivoire, Mali and Nigeria, the high prevalence of childhood illnesses such as malaria was identified as one of the causes of the high prevalence of child malnutrition[39].

  - In the Gambia, an increased prevalence of iron deficiency anaemia was observed at the end of the malaria season, among children aged 2-6 years old[33].

  - In the central Sahel, a high prevalence of childhood diseases, particularly malaria, due to lack of healthcare access is driving the high prevalence of child malnutrition[26]

  - In Ethiopia, malaria has been reported as a risk factor for stunting and wasting among young children[72].
  - In Cameroon and Côte d'Ivoire, the prevalence of anaemia is higher in populations at risk of inflammation and linked to infections (malaria, parasitosis, including schistosomiasis) and hygiene conditions[33].

- **Recent illness (e.g., diarrhoea, fever, respiratory infection)'**

  - In Côte d'Ivoire, Mali and Nigeria, the high prevalence of childhood diarrhoea and acute respiratory infections were identified as causes of the high prevalence of child malnutrition[39].

- In Ethiopia, recent diarrhoea, fever or respiratory infection was associated with an increased risk of stunting and malnutrition, among children[31,32,34].
- In the Gambia, a high prevalence of diarrhoea was significantly associated with lower height-for-age, but not with weight-for-age, this may reflect that the prevalence of diarrhoea was an indicator of unhygienic conditions in the home, with important effects on the long-term (chronic) nutritional situation[38].

- **Communicable disease':**

- In Côte d'Ivoire, Mali and Nigeria, the resurgence of measles epidemics was identified as a cause of the high prevalence of child malnutrition[39].
- In the Gambia, unclean water and infectious diseases were identified as important determinants of undernutrition among children[38]. In this country, HIV-positive children had significantly worse scores in terms of weight-for-age, height-for-age, and BMI than HIV-negative children[40].

- **Undernutrition:**

- In Burkina Faso, Ethiopia, Gambia, Ghana, Niger, Nigeria and Senegal, episodes of wasting among young children contribute to stunting and, to a lesser extent, stunting in these children may lead to wasting[52].
- In Burkina Faso, Anaemia was significantly associated with malnutrition, among children[40].
- In Ethiopia, school-aged children diagnosed with anaemia were at higher risk of stunting[28].

1.2.2 Maternal

- **Antenatal depression:**

- In Ethiopia and Ghana, depression during pregnancy was associated with a higher risk of stunting among children [57].

- **Micronutrient deficiencies:**

- In Ethiopia, a study has shown an inverse correlation between maternal micronutrient status and anaemia among breastfed children aged 6 – 23 months[33].

- **Malaria:**

- In Mali, malaria was identified as a risk factor for anaemia among women of reproductive age. An interlink with seasonality was highlighted in this study, based on a strong seasonal variation which mimics that of malaria, the fact that malaria chemoprophylaxis suppresses anaemia during the rainy season[67].

- **Nutritional Status/ BMI/ MUAC:**

- In Ethiopia, low maternal BMI (< 18.5kg/m2) was associated with a higher risk of stunting, wasting and malnutrition among under-five children [28,32,34]. Low maternal weight gain during pregnancy was associated with a higher risk of malnutrition among children[34]. In addition, mothers with MUAC <23 cm were at higher risk of anaemia[35].
- In Ethiopia and Guinea, a BMI > 18.5 kg/$m^2$ was associated with a decreased risk of developing anaemia, among women[55].
- In Ethiopia and Senegal, improvements in maternal nutritional status (*e.g.*, during adolescence and/or prior to conception) were associated with lower stunting prevalence[59].

- In Ghana, increases in maternal BMI were associated with decreasing risk of malnutrition among children[34].
- In Nigeria, low BMI was associated with a higher risk of stunting among children[32].

### 1.3. Individual characteristics

1.3.1 Child

- **Age:**

- In Burkina Faso, Mali, Nigeria and Senegal, increasing risk of stunting was associated with increasing age (in months) among children[29].
- In Ethiopia and Nigeria, both younger [23,28,29,32] and older [29,32] children have been identified as being more vulnerable to wasting. Increasing child's age (in months) has been associated with increased risk of underweight[29] and stunting [34].
- In Ethiopia, younger children were less likely to develop undernutrition if they were breastfed[61].
- In Ghana, older children were at increased risk of stunting and underweight[34].
- In Nigeria, children aged 0-23 months were at higher risk of stunting[32]. Younger infants were at higher risk of developing anaemia in another study conducted in the country[33].
- In Cameroon, children who were still breastfeeding had a higher risk of being underweight than those who had been weaned[61].

- **Sex:**

- In Burkina Faso, Côte d'Ivoire, Ghana, Mali and Senegal, male children under five were found to be at higher risk of stunting[29].
- In Cameroon, a study among adolescents showed that girls were more likely to be stunted than boys, possibly resulting from cultural preferences whereby boys have better access to food, education, and other socioeconomic facilities than girls[58].
- In Ethiopia and Nigeria, male children under five were found to be at higher risk of wasting, stunting and undernutrition[28,29,32,34]
- In Nigeria, male children under five were found to be at higher risk of underweight[32]. Another study showed that although boys were taller than girls, stunting was more pronounced in boys[58].
- In Nigeria, Ghana, Burkina Faso, Senegal and Ethiopia, boys experience more undernutrition than girls, from as early as the foetal period. Differences are more pronounced in more severe presentations of undernutrition and in more socioeconomically deprived contexts. Boys are more vulnerable to infectious disease, and differing immune and endocrine systems explain some of this disadvantage. Limited evidence also suggests that different sociological factors and care practices might exert influence and have the potential to exacerbate or reverse observed differences[63].
- In Cameroon, Ethiopia, Gambia, Ghana, Guinea and Senegal, being a girl was a protective risk factor for anaemia, among under-five children[62].

- **Birth weight:**

- In Ethiopia, low (including perceived) birth weight was observed as a risk factor for stunting, wasting and malnutrition among under-five children[28,32,34,64,65].
- In Nigeria, low birthweight was significantly associated with a higher risk of stunting among children[32].
- In Ghana, small size at birth was associated with increased risk of malnutrition[34].

- **Birth size:**

- In Ethiopia, lower birth size, was associated with higher prevalence of stunting[31].

- **Multiple birth:**

- In Ethiopia and Nigeria, under-five children who were born in multiple births (twins, triplets, …) were associated with a significantly higher risk of stunting [28,32].
- In Ghana, multiple birth was associated with a significantly higher risk of malnutrition, among children[34].

- **Birth order:**

- In Nigeria, a higher birth order, meaning, for example, not being the first child, or and order greater than the third or fifth child was associated with a higher risk and as a mitigating factor for stunting, in two different studies conducted in the country[29].

1.3.2 Maternal

- **Age:**

- In Ethiopia, higher maternal age at the time of birth was associated with increased risk of wasting among children[32]. Maternal or caregiver age below 35 years old was a protective factor for wasting among school-aged children[28].
- In Nigeria, maternal age of 35 years old and above was a protective factor for stunting and underweight among children [29,32].
- In Ghana, increases in maternal age were associated with lower malnutrition among children[34].

- **Height:**

- In Ethiopia, short maternal height was associated high a higher risk of stunting and wasting among under-five children[31,32,34].
- In Ghana, higher maternal height was identified as a mitigating factor for stunting, among children[29].

- **Lower parity/ Shorter Interpregnancy interval:**

- In Ethiopia, a shorter interpregnancy interval among children it was associated with increased risk of malnutrition among children[34] and with increased risk of anaemia, among women[35].
- In Ethiopia and Senegal increasing interpregnancy intervals were strong contributors to improvements in stunting prevalence[59].
- In Mali, the presence of Anaemia (and malaria) was higher among in women of low-parity[67]
- In Senegal, lower parity was associated with increased risk of undernutrition among women[54].
- In Nigeria, it was associated with increased risk of stunting among children[32]

## 2. Underlying drivers:

### 2.1 Insufficient household food security

- **Food insecurity status:**

  - In Ghana, the relationship between food insecurity and stunting was stronger in children aged at least 23 months[71].
  - In Ethiopia, high food insecurity among children aged 6-59 months was associated with higher stunting and wasting prevalence[72]. High household food insecurity was associated with higher prevalence of stunting and underweight among children[71]. Lower food insecurity has been identified as a mitigating factor for wasting[29]. High insecurity at both individual and household levels were associated with undernutrition among adolescents[73]. Increased consumable crop yield was associated with decreased stunting in the country[59]. Moreover, one of the country's solutions to food insecurity induced by the COVID-19 pandemic was aimed at providing emergency food aid to 15 million individuals vulnerable to food insecurity and was considered important to the country's stunting reduction[70].
  - In Burkina Faso, Cameroon, Chad, Mali, the Niger and Nigeria, elevated levels of acute food insecurity were a major contributing factor to the deteriorating nutritional status of children. In these countries, conflicts and insecurity have triggered mass population displacements, disrupting access to food sources, livelihoods and essential services, decreasing production, pushing up food prices and hindering the distribution of humanitarian food assistance. In areas hosting international displaced persons, such as Far-North, Littoral and West regions of Cameroon, the nutrition situation was concerning due to increased demand on limited food stocks[26].
  - In Nigeria, a positive association was identified between food insecurity and wasting[72].

- **Household agricultural/livestock production**

  - In Ethiopia, it was associated with decreased risk of stunting[27][29], among children[32]. Increased consumable crop yield was associated with decreased stunting in the country[59]. Household possession of livestock was associated with a higher risk of wasting among children[29]

### 2.2 Inadequate care environment

- **Poor breastfeeding practices:**

  - In Nigeria and Ethiopia, respectively, lower duration or non-exclusive breastfeeding during the first six months of life was reported as risk factors for anaemia in infants and children aged 1-5 years old. Longer breastfeeding duration was also identified as a risk factor for anaemia among children aged 1-7 years old in Nigeria[33].
  - In Ethiopia, the mothers who breastfed for two years had significantly lower risk of developing anaemia, in comparison with women who breastfed for one year[55]. Longer duration of breastfeeding was associated with a higher risk of stunting, and lower risk of wasting, among Ethiopian children[32,64,72]. Delayed initiation of breastfeeding after one hour after birth was significantly associated with a higher risk of stunting, among Ethiopian children[28]. Another study observed that children breastfed for <2 years and children breastfed for <6 months were at higher risk of stunting[75].

- In Ghana, longer breastfeeding duration was associated with increased risk of malnutrition, among children[34].
- In the Sahel, inadequate child-feeding practices and low breastfeeding rates are related to, among other factors, cultural taboos relating to food choices, leading to malnutrition among children[26].

- **Poor complementary feeding practices:**

- In Ethiopia, a higher prevalence of stunting has been detected when children started complementary feeding after 6 or 12 months of age[31].

- **Family structure:**

- In Nigeria, the lack of adequate childcare for orphaned, abandoned and separated children is a major contributor to wasting[26].

- **Stress of displacement:**

- In Eastern Chad, during the Chadian Civil War, mass population displacement had an intermediate role between armed conflict and food insecurity and undernutrition, for both displaced and non-displaced populations (due to limited access to food) [42].

## 2.3 Insufficient health services and unhealthy environment

### 2.3.1 Insufficient health services

- **Access to health services:**

- In Burkina Faso, Chad, Cote d'Ivoire, Gambia, Ghana, Guinea, Mauritania, Niger, Nigeria and Senegal, access to health services were identified as major factors impacting the nutritional status of children under five. However, in the region, many health centres are closed due to civil insecurity[39].
- In the Central Sahel, many families do not have access to medical care with health centres shut while most of the ones still open are not fully functional (due to conflicts). A high prevalence of childhood diseases (particularly malaria, diarrhoea and acute respiratory infections) and a resurgence of measles outbreaks in Côte d'Ivoire, Mali and Nigeria are also driving the high prevalence of child malnutrition[26]
- In the Sahel, the economic crises and the impacts of COVID-19 are preventing a rising number of households and communities from accessing basic social services, healthcare, sanitation, safe drinking water and hygiene, leading to increased malnutrition among children[26].

- **Antenatal care:**

- In Ethiopia, it was observed, among lactating women, that those who reported receiving antenatal care visits during their pregnancy were at lower risk of being anaemic [35] and of having underweight or stunted children, compared to those who did not receive visits [34,54,55]. Children whose mothers reported receiving antenatal care were at higher risk of wasting[34].
- In Ethiopia and Senegal, improved access to antenatal care was associated with decreased stunting prevalence[59].
- In Senegal, women who reported receiving four or more antenatal care visits during their pregnancy were at lower risk of having stunted children[54].

- **Contraceptive use:**

  - In Ethiopia, contraceptive use was associated with decreased anaemia among women[55].

- **Poor maternal health seeking behaviours:**

  - In Nigeria, poor maternal health seeking behaviours were associated with increased risk of stunting among children[32].

- **Vaccination/Immunisation:**

  - In Ethiopia, child's immunisation status was inversely associated with the risk of stunting, among children[28,32].

- **Supplementation:**

  - In Ethiopia, women not taking iron-folic acid during pregnancy were at higher risk of anaemia[35].

- **Maternal care:**

  - In Ethiopia and Senegal, improved access to maternal care was associated with decreased stunting prevalence[59].

- **Place of birth delivery/ access to skilled birth**

  - In Ethiopia, caesarean and non-caesarean birth delivery at a health facility, in comparison with home delivery, was associated with lower risk of development of severe wasting among under-five children. Caesarean birth at a health facility was also associated with lower risk of moderate wasting[32].

  - In Senegal, a combined measure of increases in coverage in four or more antenatal visits plus attending a skilled birth (or a birth in a health facility) accounted for 34% of the stunting decrease in Senegal[54].

- **Health insurance:**

  - In Ghana, children whose mothers who are not covered by national health insurance were at higher risk of malnutrition[34].

2.3.2 Unhealthy environment

- **Water, sanitation and hygiene (WASH) conditions**

  - In Mali, a study suggested that WASH interventions may result in decreased undernutrition through an effect on decreasing Environmental Enteric Dysfunction[46].

- **Housing conditions:**

  - In Ethiopia, the likelihood of being stunted was found to be approximately three times higher among children whose house floor is earth than children who have a house with wooden type of floor[31,34].

- **Open defecation:**

  - In Ethiopia, open defecation has been identified as a risk factor for malnutrition[34]. Moreover, reductions in open defecation at national level led to an eight percent decrease of stunting prevalence in the country [54,59].

- **Improved sanitation infrastructure:**

- In Guinea and Ethiopia, it was found to inversely associated with the risk of stunting among children [32,34,54].
- In Ghana, absence of toilet facilities in households was associated with increased risk of malnutrition[34].
- In the Sahel, the economic crises and the impacts of COVID-19 are preventing a rising number of households and communities from accessing basic social services, healthcare, sanitation, safe drinking water and hygiene, leading to increased malnutrition among children[26].

- **Exposure to outdoor air pollution/biomass smoke/ polycyclic aromatic hydrocarbons (PAHs)**

- In Ghana, a study conducted among street vendors has shown that exposure to outdoor air pollution and biomass smoke are associated with low birth weight, stunted growth and negative birth outcomes[79].

- **Water insecurity:**

- In Ghana, a multicounty study including data from rural populations, observed a potential relationship between water insecurity and higher risk of stunting [77].
- In Senegal, improved access to a safe water source was associated with a 6% decrease of stunting prevalence[54].
- In Ethiopia, school-aged children whose water source was non-pipped water at higher risk of stunting [28].
- In the Gambia, lower water quality was associated with higher levels of stunting among children[38].
- In the Sahel, the economic crises and the impacts of COVID-19 are preventing a rising number of households and communities from accessing basic social services, healthcare, sanitation, safe drinking water and hygiene, leading to increased malnutrition among children[26].

- **Type of cooking fuel:**

- In Ethiopia, the use of traditional fuel (charcoal, wood, animal dung, and other agricultural crops and straw) for cooking, in comparison with modern fuel (electricity, natural gas, biogas, and kerosene), was associated with a higher risk of stunting among under-five children[31,32,34].

- **Aflatoxin exposure:**

- In the Gambia, exposure to aflatoxin was associated with increased stunting or underweight among children[80].

## 3. Basic/systemic drivers:

### 3.1 Livelihood resources, strategies and goals

- **Household/maternal wealth/wealth index/ increased poverty:**

- In Ethiopia, higher household wealth was associated with decreased anaemia prevalence among women[55] and lower household wealth was associated with increased risk of stunting, among children[31,34].
- In Ethiopia, Nigeria and Ghana, household wealth was associated with the risk of wasting, stunting and wasting among under-five children[28,29,32].

- In Ghana, household wealth was negatively associated with the risk of anaemia[55].
- In Mali, Chad, Niger, Mauritania, Burkina Faso and Nigeria, countries with a high prevalence of acute undernutrition among under-five children, increasing household food insecurity was concomitantly observed (2021 data)[30].

- **Loss of family providers:**

- In Ethiopia, during the Ethiopian Civil War, forced military conscription led to the decrease of labour force to sustain agricultural production, at the household and community levels, thus leading to food insecurity and undernutrition [42].

- **Human capital:**

- In the Sahel, diminish human capital of the households was identified as a risk factor for malnutrition. Physical destruction of human capital happens when there is a large-scale conflict or high mortality epidemiological events, droughts and floods, when they destroy crops and livestock assets[82].

- **Lower maternal/paternal or parental education:**

- In Cameroon, Ethiopia, Gambia, Ghana, Guinea and Senegal, informal maternal education was associated with a higher risk of stunting [62].
- In Ethiopia, lower maternal education was associated with increased anaemia among women[35] and with a higher risk of stunting and malnutrition, among children[31,34,61]. Secondary maternal and paternal education and above were associated with decreased risk of stunting among under-five children[32].
- In Ethiopia and Senegal, child stunting prevalence was consistently higher in the least educated mothers[59].
- In Guinea and Nigeria, Lower maternal education was associated with increased risk of stunting among children [29,32,54] and with increased risk of underweight in Nigeria[29].
- In Guinea, Ghana, Ethiopia and Senegal, higher paternal and/or parental education were associated with decreased risk of stunting [29,54].
- In Nigeria, higher maternal and paternal education was associated with lower risk of stunting, wasting and underweight among children[29,32].

- **Maternal occupation/ unemployment:**

- In Ethiopia, a higher prevalence of anaemia was observed among unemployed women[55]. Another study observed that children whose mother's main occupation was non-farm were associated with wasting[34].

- **Urban/rural residence:**

- In Ethiopia, urban residence was protective against anaemia in women of reproductive age[35].
- In Ethiopia, Nigeria and Côte d'Ivoire, rural residence was associated with a higher risk of stunting among under-five children[28,29,32].
- In Ethiopia and Senegal, families living in rural areas had higher stunting prevalence[59].
- In Ghana, a significantly higher anaemia prevalence was found among rural women, comparing to those living in urban areas[68].

- In Nigeria, rural residence was associated with lower risk of wasting among under-five children[32]. In another study, adolescents in rural schools were much more likely to be stunted than those in urban private schools. Stunting and underweight were most severe among rural adolescents[58].
- In Cameroon, Ethiopia, Gambia, Ghana, Guinea[62].

- **Ownership of television:**

- In Ethiopia, not watching tv was associated with a higher risk of moderate and severe wasting among children[32].

- **Household/family size/ Number of children <5 years/ Dependency ratio:**

- In Cameroon, Ethiopia, Gambia, Ghana, Guinea and Senegal, lower family size was a protective risk factor for anaemia, among under-five children[62].
- In Ethiopia, higher household size was identified as a risk factor for stunting and for underweight and also as a mitigating factor for wasting among children[29,34]. Among women, a lower household size was protective against anaemia[35].
- In Ethiopia, a higher family size was associated with a higher risk of stunting, among children[31].
- In Ethiopia, a higher number of children below five years of age in the household was associated with a higher risk of stunting, among children. The number of children <5 years of age may be correlated with short birth spacing[31].
- In Ethiopia, a higher dependency ratio was associated with increased risk of stunting, among children[31].

- **Sex of the household head:**

- In Ethiopia, the household head being female was associated with a higher stunting prevalence among children[31].

### 3.2.1.Governance and political economy

- **Political economy:**

- In Cameroon, severe economic crises were associated with increased prevalence of stunting (from 23% to 29%) and being underweight (from 16% to 22%) among children under three years old[24].
- In Ghana, according to a cross-country study aiming to examine under-five stunting trends, economic growth and poverty reduction are associated with lower child under-nutrition[54].

- **Human-induced disasters:**

- In Ethiopia, a meta-analysis of studies conducted in the country concluded that conflict triggers undernutrition and food insecurity through multiple pathways: it often leads to disruption of crop production, destruction of food stores and livestock, compulsion of people to eat foods with lower nutritional value, disruption of market food supplies and price inflation, compulsion of people to live in unhealthy environments, degradation of health services, and degradation of productivity. Moreover, higher pooled prevalence of wasting was observed in conflict-affected areas than in non-conflict-affected zones within this country[85] (exceeding the WHO emergency response threshold of 10%, indicating severe concerns for child undernutrition[23]).
- In Burkina Faso, Chad, Mali, Mauritania, Niger and Nigeria, countries where the prevalence of undernourished children is already high, the rate is expected to increase further, aggravated by

the conflict Ukraine-Russia, because of diminished cereal imports[30]. Armed attacks on communities, schools, health centres and other public institutions and infrastructure led to massive population displacement and, consequently, disrupted livelihoods and access to social services including education and health care, resulting in increased acute malnutrition among under-five children in countries in the Sahel (2019-2021 data)[30].

- In the Sahel, diminish human capital of the households was identified as a risk factor for malnutrition. Physical destruction of human capital happens when there is a large-scale conflict or high mortality epidemiological events, droughts and floods, when they destroy crops and livestock assets. rainfall failure[82].
- In Burkina Faso, Cameroon, Chad, Mali, the Niger and Nigeria conflicts and insecurity have triggered mass population displacements, disrupting access to food sources, livelihoods and essential services, decreasing production, pushing up food prices and hindering the distribution of humanitarian food assistance, leading to high prevalence of food insecurity. In areas hosting international displaced persons, such as Far-North, Littoral and West regions of Cameroon, the nutrition situation was concerning due to increased demand on limited food stocks[26].

- **Other disasters:**

- In the Sahel, the economic crises and the impacts of COVID-19 are preventing a rising number of households and communities from accessing basic social services, healthcare, sanitation, safe drinking water and hygiene, leading to increased malnutrition among children[26].

- **Emergency preparedness:**

- In Burkina Faso, Ethiopia, Gambia, Ghana, Mali, Niger and Nigeria, emergency preparedness was the least implemented aspect of policies under the "Global Strategy for Infant and Young Child Feeding 2008-2016" [23], of which one of the main goals was undernutrition prevention.

- **Poverty:**

- In Northern Nigeria, widespread poverty was identified as a major trigger for child malnutrition[23].

- **Insecurity:**

- In Northern Nigeria, insecurity was identified as a major trigger for child malnutrition[23].
- In the Sahel, communal conflicts and political instability, characterised by coups and low scale violence, were considered risk factor for malnutrition[82].
- In Burkina Faso, Cameroon, Chad, Mali, the Niger and Nigeria conflicts and insecurity have triggered mass population displacements, disrupting access to food sources, livelihoods and essential services, decreasing production, pushing up food prices and hindering the distribution of humanitarian food assistance, leading to high prevalence of food insecurity. In areas hosting international displaced persons, such as Far-North, Littoral and West regions of Cameroon, the nutrition situation was concerning due to increased demand on limited food stocks[26].

- **Illiteracy rate:**

- In Nigeria, an increased risk of stunting was observed among children, in communities where the illiteracy rate was high[32].

- **Urbanisation:**

- In Senegal, urbanisation was identified as a protective factor for undernutrition, among children[40].

- **Migration/ population displacement:**

- In Burkina Faso, Cameroon, Chad, Mali, the Niger and Nigeria conflicts and insecurity have triggered mass population displacements, disrupting access to food sources, livelihoods and essential services, decreasing production, pushing up food prices and hindering the distribution of humanitarian food assistance, leading to high prevalence of food insecurity. In areas hosting international displaced persons, such as Far-North, Littoral and West regions of Cameroon, the nutrition situation was concerning due to increased demand on limited food stocks[26].

### 3.2.2 Food and Health systems

#### 3.2.2.1 Food systems

- **Foreign embargos/ "Food as a weapon of war":**

- In Ethiopia, military restrictions of humanitarian aid organisations into conflict zones during the Eritrean-Ethiopian War led to limited access of food for the populations, contributing to increased undernutrition and food insecurity [42].

- **Household access to irrigation:**

- In the Gambia, higher levels of stunting and wasting were found in children without access to irrigation; underweight prevalence was higher among children with access to irrigation[38].

- **Disrupted access to food sources:**

- In Burkina Faso, Cameroon, Chad, Mali, the Niger and Nigeria conflicts and insecurity have triggered mass population displacements, disrupting access to food sources, livelihoods and essential services, decreasing production, pushing up food prices and hindering the distribution of humanitarian food assistance, leading to high prevalence of food insecurity. In areas hosting international displaced persons, such as Far-North, Littoral and West regions of Cameroon, the nutrition situation was concerning due to increased demand on limited food stocks[26].

#### 3.2.2.2 Health systems

- **National Nutrition policy:**

  - In Ethiopia, a study comparing the effect of child nutrition policy found impressive improvements, including decreased stunting, wasting, and underweight prevalence[24].

- **Low health system quality/ Health system degradation:**

  - In Northern Nigeria, poor health care is a major trigger for child malnutrition [23].

  - In Ethiopia, during the COVID-19 pandemic, the model implemented to mobilise community health workers to deliver vaccines, nutritional supplements, health and nutrition education, and even reproductive, maternal, and new-born care was considered successful for mitigating the negative impacts on children's nutritional status[70].

### 3.2.3 Gender, cultural and social norms

- **Cultural norms and behaviour/ health & food beliefs:**

- In Nigeria, a study focused on identifying drivers of undernutrition concluded that, in the country, misconceptions, cultural practices, and other beliefs drive inadequate child feeding practices, household health, agriculture, and WASH behaviours [23].

- In the Sahel, cultural taboos relating to food choices underlie poor food consumption patterns, inadequate child-feeding practices and low breastfeeding rates, which conjugated with lack of access to healthy diets, lead to malnutrition among children[26].

- **Religion:**

- In Ethiopia, under-five children from Muslim, Orthodox and other traditional religion followers were at increased risk of stunting, relative to children of the protestant community[28,32]. Being Christian was associated with decreased risk of wasting [32].

- **Women empowerment:**

- In Ethiopia, women's empowerment had a positive influence in reducing stunting, due to an increase in women's social independence and household decision-making in parenting of feeding practices and food diversity to improve nutritional status[88,89].

- In Ethiopia and Mali, lower household decision-making authority for women was associated with lower child nutritional status and with poorer health among Ethiopian women, namely higher risk of Anaemia[86].

### 3.3. Environment and seasonality

#### 3.3.1 Climate variability

- **Natural disasters:**

- In Cameroon, natural disasters have shown to have long-term impacts on child's nutrition status, due to disruptions in food supply and/or diarrheal illness caused by contaminated water[24].

- In Ethiopia, one of the country's solutions to food insecurity induced by the COVID-19 pandemic was aimed at providing emergency food aid to 15 million individuals vulnerable to food insecurity and was considered important to the country's stunting reduction[70].

- In the Sahel, diminish human capital of the households was identified as a risk factor for malnutrition. Physical destruction of human capital happens when there is a large-scale conflict or high mortality epidemic - pests, droughts and floods, when they destroy crops and livestock assets. rainfall failure[82].

- **Aridity/drying:**

- In the Sahel, the drying of the lands, and subsequent changes to social organisations and livelihoods, have been identified as risk factors for Malnutrition[82].

- **Rainfall failure:**

- In the Sahel, rainfall failure has been identified as a risk factor for Malnutrition[82].

- **Floods:**

- In northern Ghana, the increasing frequency of flood associated with climate change, leads to declined agricultural and livestock production, resulting in a decreased state of food production and increased food insecurity and high malnutrition[37].

#### 3.3.2 Seasonality

- **Seasonality:**

- In Burkina Faso, Chad, Mali, Mauritania, Niger and Nigeria, countries where the undernourishment prevalence is already high, it is expected to increase in lean seasons (2021 data)[30].
- In Gambia, there is a trend of decreasing anaemia during the dry season and increasing with greater rainfall, low and cold temperatures[67]. The increased anaemia amid the rainy season has been explained, by other authors, as a combination of food shortages and infestations (*e.g.*, hookworm) during the farming season in the country[67]. In rural Gambia, season can strongly influence children's nutritional status[80]. In general, the prevalence of undernutrition in the country was higher in the wet season, when food supplies are lower; this effect was more significant for wasting, as weight-for-height values reflect the short-term (acute) nutritional situation[38].

## 4.3 Implications for indicators' use to assist nutrition programming in the Sahel

The main research output of this study is a list of drivers of undernutrition in the Sahel and in Sahelian countries, based on evidence from published literature. The purpose of the subsequent components of the broad study "Drivers of Persistent High Rates of Undernutrition in the Sahel" will be to systematically analyse the available data on these drivers in the Sahel region 1 through artificial intelligence and machine learning algorithms to explore potentially complex and non-linear relationships between multiple factors drivers. The two components should not be taken independently.

In fact, considering that published reports may be biased towards specific countries and specific targets, when interpreting the results of the current report, one must reflect on the following:

- The higher reporting of a given driver associated with nutrition outcome(s) in the Sahel may not represent a higher significance; similarly, lower reporting frequency may not also represent lower significance[2]. In addition, it is hypothesised that a considerable proportion of local studies (*e.g.,* surveys) may be conducted by master of PhD students and are not published or may not be published in international journals and/or indexed.

- When designing nutrition programmes, 1) not addressing less reported drivers or 2) concentrating efforts to address a dimension of the UNICEF Undernutrition framework (e.g., within immediate drivers) and disregarding other dimensions (*e.g.,* within basic/systemic drivers), may be parts of the explanation for persistent undernutrition in the region.

- Focusing on a given dimension of the UNICEF/Young Undernutrition framework may not represent a higher significance.

As such, the list informs a collective discussion of what is known and published and what is unnoticed and can be disclosed by machine learning algorithms. The hypothesis is that by comparing both lists, a new understanding of the lack of success of previous support and novel approaches for monitoring and guiding nutrition programming in the Sahel can be suggested. Most importantly, one aims at capturing explanations in non-linear relationships between drivers and in complex interactions between them.

Additionally, in this study, lack of published evidence was disclosed concerning i) reviews of undernutrition drivers specifically focused on the Sahel region, ii) drivers of anaemia in women of reproductive age, and iii) drivers of wasting among (under five) children.

[2] Nonetheless, more published results increase the evidence base for that context and lack of studies implies limited information on context specific factors.

Nonetheless, some implications for the planning of nutrition interventions can be endorsed by the main findings, as discussed in the following subsections.

### 4.3.1 Concerning what is reported for the Sahelian context

- The countries for which more information on reported undernutrition drivers is available are those where population surveys such as the Demographic Health Survey are frequently implemented to monitor health and development outcomes (*e.g.,* Ethiopia, Ghana, Nigeria and Burkina Faso). This is reflected in many drivers for which information is commonly collected in those surveys, such as low dietary diversity, minimum acceptable diet, nutritional status of both the child and the mother, age, sex of the child and other immediate drivers. These standardised data collections are important given the scarcity of local research and quality data [(21)].

- There is a lower availability of data for indicators in the underlying and basic/systemic dimensions. This is important since data on these dimensions is not collected by the DHS or other population surveys conducted by international agencies. This might reflect the need to re-think future studies that rely on data sources beyond population surveys.

- Regarding undernutrition outcomes among children, both children's and maternal characteristics affecting dietary intake and disease were identified. This underscores the importance of good maternal health and nutrition in the child's development and also prevention of undernutrition. However, the UNICEF/Young Undernutrition framework lacks differentiation between children's and maternal characteristics, by not addressing them in separate dimensions. It might be pertinent to revise this when designing a framework specifically for the Sahelian countries, given the high proportion of young and undernourished mothers and the absence of adequate health services that may affect not only the children's but also maternal health status. Increased focus on maternal health and nutrition should be emphasised in both nutrition research and programming.

- Likewise, several individual characteristics among children (*e.g.,* age, sex, birth order, type of birth, low birthweight, birth size and preterm birth) and among mothers or caregivers (*e.g.,* age, early onset of childbearing, low parity/short interpregnancy intervals, first pregnancy, pregnancy or breastfeeding status and height) were identified as drivers of undernutrition. Such characteristics are not clearly identified in any of the dimensions integrating the UNICEF/Young Undernutrition framework. Given the relevance of these indicators in the Sahelian context, these were tentatively integrated within an "orphan category" named "individual characteristics" and then subdivided into "children" and "maternal" (as immediate drivers). This specific visualisation drawn by disaggregating some dimensions of the comprehensive conceptual model, vis-à-vis the conceptual comprehensive model, was instrumental to explain overlooked explanatory aspects that are local and characteristic of the Sahel.

- The Sahelian context presents distinctive characteristics at different demographic, societal and environment levels, reflected in dimensions such as livelihoods, culture and gender, health and food systems, environment and seasonality, and also political stability and conflicts. Although the UNICEF/Young framework accounts for these dimensions, when analysing the considerable number and diversity of drivers and indicators that emerged from the literature, it was hypothesised that, in the Sahelian context, it might be pertinent to subdivide some of the dimensions, in order to better aggregate indicators that may be more inter-related and, in so, to illuminate on relevant causes of undernutrition in the region. Sahelian countries show specificities such as undeveloped food systems (close to farming systems due to poor or absent linkages with the market)[(93)], [insufficient/not structured] health systems that are not embedded in the socioeconomic/natural environment, harsh agroecological conditions prone to extremes and climate shocks, or farming systems characterised by strong seasonality. Keeping the same rationale that recommends integrating a novel category in the dimension of immediate drivers, the results reported, contextualised for the Sahel, suggest sub-clustering i) "Inadequate social & care environment" into "insufficient health services"

and “unhealthy environment”, ii) “Food and health systems” into “Food systems” and “Health systems”, and iii) “Environment & seasonality” into “Climate variability and extremes” and “Seasonality”. A proposed version for an updated framework accounting for the identified challenges is presented in figure 4.

- When considering the different undernutrition outcomes analysed:

- As expected, there is some variation among some dimensions of drivers. For example, while increasing age (in months) among children was associated with increasing risk of stunting, younger children have been identified as being more vulnerable to wasting. This may reflect the fact that wasting is often associated with short-term factors such as seasonal variations in food availability, acute food shortages, changes in socioeconomic policies, and diseases emerging beyond the expected level, while stunting is the result of impaired growth and development that children experience from poor nutrition, repeated infection, and inadequate psychosocial stimulation [90,91,92,93].

- Nevertheless, there is some evidence that stunting and wasting may have “shared” drivers[13] . As such, it may be relevant to further disentangle the proposed framework according to the different undernutrition outcomes studied, to gather more insight into the specific or “shared” drivers of each undernutrition outcome (both among children and among women of reproductive age). This may contribute to better design food and nutrition strategies at regional and country levels, if the burden of undernutrition is widely acknowledged. For instance, a country where the persistence of wasting is more burdensome than the persistence of stunting, the strategies to implement might be more targeted for the immediate/underlying drivers, rather than the basic/systemic. Contrarywise, if there is a high prevalence of concurrent wasting and stunting, it may be more strategic to tackle common drivers.

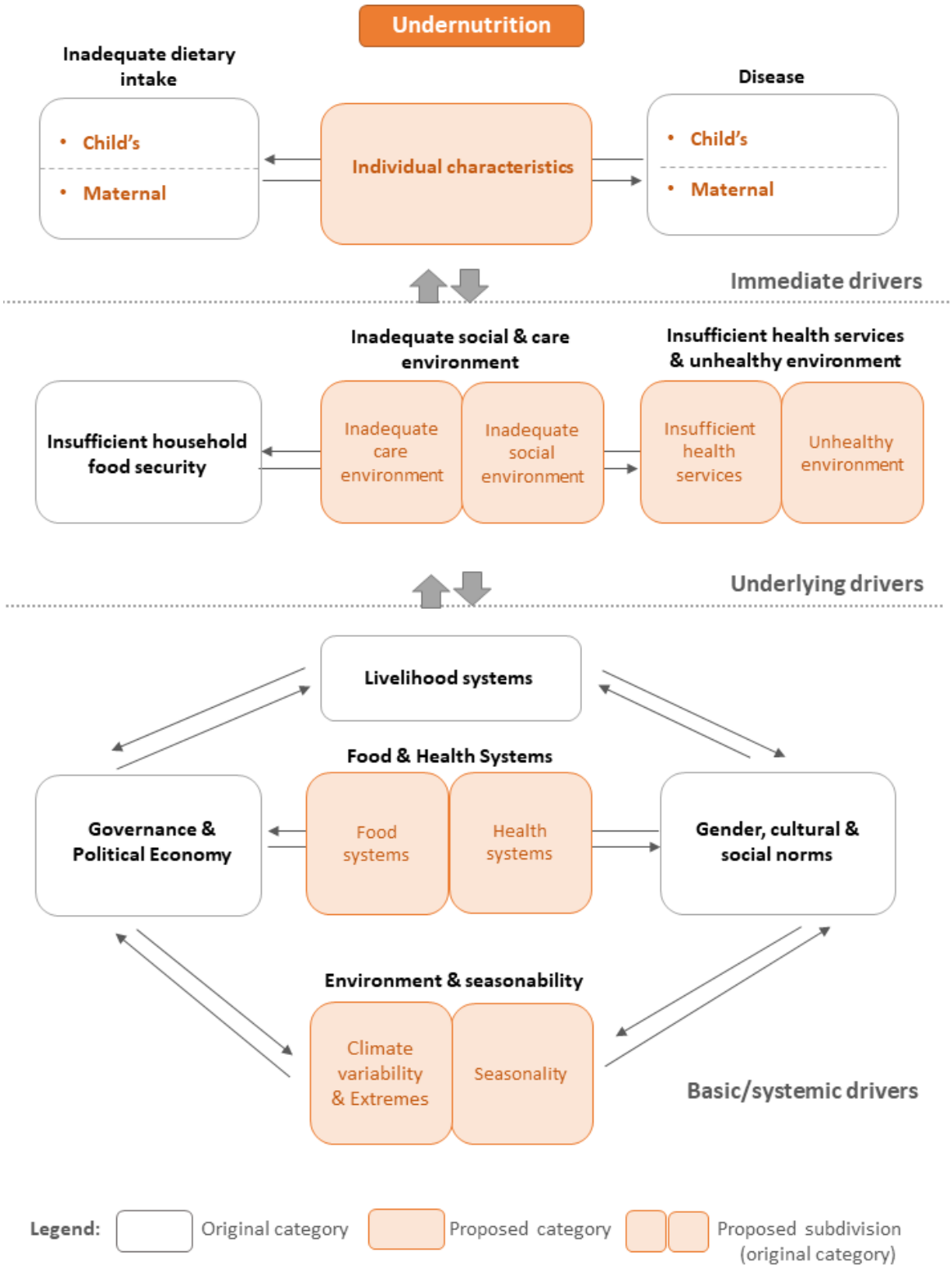



***Figure 4**. Proposed representation of the framework of drivers of undernutrition contextualized for the Sahel.*

### 4.3.2 Concerning what is reported in the global LMICs context:

- Within each dimension, a significant set of specific drivers of undernutrition are widely described in LMICs, taken as a whole, but not reported when the Sahelian context is considered. A full list of the undernutrition drivers identified in other LMICs, but not In the Sahel is depicted in Table 6. For example, no specific undernutrition drivers were identified in Sahelian countries for two dimensions, "Diseases – Household and/or community level" (immediate drivers) and "Inadequate social & care environment– Access to social services" (underlying drivers).

- By focusing on literature reviews, this study may not capture the whole spectrum of publications of drivers of undernutrition in the Sahel. Despite this limitation, the fact that some of the undernutrition drivers described in other LMICs with severe undernutrition burdens have not been identified in the region is highly relevant (Table 6). Such underrepresentation may suggest that these drivers are not relevant in the Sahelian context. However, they may be relevant but 1) still ignored in the region, hampering targeting successful nutrition interventions or 2) indeed understudied, unpublished or not indexed, due to a variety of reasons associated with absence of funds, human resources, etc. [21]. Studying these "non-identified drivers" more in-dept might provide some clarity for further insights into the causes of persistent undernutrition and support the design of more effective programs and interventions. Again, an integrated analysis with the results of component two will add further knowledge to this observation.

***Table 6.*** *Drivers of undernutrition identified in the review, by dimensions and categories, which have not been described in countries in the Sahel (n=72 publications).*

| Drivers of Undernutrition |
|---|
| **1.IMMEDIATE:** |
| **1.1.Inadequate dietary intake** |
| **1.1.1.Child** |
| Low energy intake [28,33]/ Low dietary energy supply per capita [29] |
| Low protein intake [25,33] |
| Low micronutrient intake: iodine [25,33], Zn [25,33], Vitamin A [32], Iron [27] |
| Diet quantity [23] |
| Geophagia [33] |
| Diet quality of food aid: low in protein [23] and vitamins [23], small rations [24], low acceptability [24] |
| Food digestibility [23] |
| **1.2.Disease** |
| **1.2.1.Child** |
| Disease/disability/morbidity [22,60]/ High incidence of childhood illnesses [30] |
| Non-communicable diseases [41] |
| Food allergy [23] |
| Nutrition/mineral/vitamin deficiencies–[54]– - iron [32,73], Vitamin A [32] |
| Malabsorption malnutrition [42] |
| Suppressed immune system [41] |
| Genetic variations enhancing iron absorption [33] |
| Low levels of physical activity [22] |
| **1.2.2.Maternal** |
| Adolescent health and nutrition [41] |
| Maternal stress [42,94] |
| **1.2.3.Household/community/national** |
| Stress and psychological trauma - household level [23] |
| Household HIV status [32] |
| Community HIV prevalence [32] |
| Disease burden (national) [83] |
| **1.3.Biological/Individual characteristics** |
| **1.3.1.Child** |
| Preterm birth [28,66] |
| **1.3.2.Maternal/caregiver** |
| First pregnancy (primigravidae) [67] |

| |
|---|
| Pregnancy status [55] / breastfeeding status [32] |
| **2.UNDERLYING:** |
| **2.1.Insufficient household food security** |
| Food access/availability [22,37] |
| Food utilisation [22,37] |
| High Food price / low affordability [22,23,26,90] |
| Cooking & storage facilities [41]/ cooking area [34]/ Ease of food preparation and storage [23] |
| Food safety [22,23] |
| **2.2.Inadequate social & care environment** |
| **2.2.1.Inadequate care environment** |
| Poor feeding practices (e.g., non-adherence towards WHO optimal feeding recommendations) [26,30,52,60,70] |
| Use of formula/ infant-feeding products [22,23] |
| Nutrition awareness/education: poor maternal awareness of child's nutritional status/ knowledge on care and feeding practices, maternal chores or livelihoods, and family eating behaviours (e.g., who eats first; the size of ind. rations) [28,48,75,89] |
| Poor stimulation/nurturing during infancy [25] |
| **2.2.2.Insufficient social services** |
| Access to social protection system/ social services [26,74] |
| Limited / interrupted social safety nets [70] |
| Interrupted / discontinued education for children and adults [30,70] |
| **2.3.Insufficient health services & unhealthy environment** |
| **2.3.1.Insufficient health services** |
| Healthcare services/ systems availability [22,23,26,30,39,59,70] |
| Healthcare quality/ Limited service and supplies for regular maternal and childcare delivery (e.g., immunisation) [70] |
| Early detection and treatment of wasting [26] |
| Access to new-born care [59] |
| Access to support for breastfeeding, feeding and care practices for young children [26] |
| Access to malaria prophylaxis [55] |
| Access to deworming in the last 6 months/Deworming status [32,60] |
| Health costs [54,56] |
| **2.3.2.Unhealthy environment** |
| Access/ type of [29]toilet facilities [32]/ Personal latrine ownership [47]/ Proportion of latrines available in the household or neighbourhood [47] |
| Exposure to lead (e.g., through artisanal gold mining) [95] |
| Exposure to pesticides [25] |
| **3.BASIC/SYSTEMIC:** |
| **3.1.Livelihood systems** |
| **3.1.1.Livelihood resources, strategies & goals** |
| Low household socioeconomic status [22,27–29,31,33,34,41,52,55,58,59] |
| Low Income/Reduced income and limited financial resources [26,38,48,54,58,69,70] |
| Reduced purchasing/spending power [26,70]/ Household food share of total expenditure [32] |
| Living in evacuation shelters or temporary housing [22,23,48,58]/ Displaced families residing in camps [26] |
| Household materials quality [29]/ Housing or household conditions [32,59] |
| Access to electricity [41,48,58] |
| Household assets [41]/ Ownership of saving accounts [41] |
| Farming community (vs. Pastoralist)/ Pastoralism [34,68,96] |
| Slum residence [28] |
| Access to roads [41] |
| Ethnic groups [23] |
| Religious groups [23] |
| Indigenous [29] |
| Property damage [56] |
| Changes to livelihoods [82] |
| **3.2.Systems, formal & Informal institutions** |
| **3.2.1.Governance & Political Economy** |
| Country/regional development [23,41,48,56,59] |
| Gross Domestic Product per capita [29,32] |
| Price shocks/inflation [23,82]/ Price volatility associated with seasonality [82] |
| Equitable economic growth [48]/ Out of pocket spendings [59] |
| Investments in health and nutrition [48]/ Health spending [59]/ Deprioritised context and compromised enablers (e.g., policy diversion to urgent care, reduced social sector spending or diversion to COVID response, increased inequity) [70] |
| Enabling environment: Capacity building [22]/ Domestic resources mobilisation [22] |
| Employment rate [54] |
| Sociodemographics [22]/ Female to male life expectancy [29]/ Population density/overcrowding [41] |
| Political instability [82]/ Politics [22] |

| |
|---|
| **3.2.2.Food & Health systems** |
| **3.2.2.1.Food Systems** |
| Agriculture [23]/ Type of agriculture (rainfed vs…?) [41] |
| Low crop production/crop yields/food harvest [23,26,37,56,59,82] |
| Crop nutrient density [22]/ Nutritional value of crops (e.g., Iron content of soils and crops) [33,56] |
| Crop diseases (changes in the dynamics) [56] |
| Destruction of agriculture and persistent insecurity [42] |
| Low livestock production [23,82] |
| Food shortage/ food scarcity/ limited food stocks/ food environment disruptions [22,26] |
| Access to public infrastructure (e.g., food stores [23], supermarkets [41]) |
| **3.2.2.2.Health Systems** |
| Health worker availability [59] |
| Nutrition programming [22] |
| Maternal, new-born and child health programs/care [54,59] |
| Health policies and systems [55] |
| **3.2.3.Gender, cultural & social norms** |
| (In)equality [22] |
| Empowerment [22] |
| Fertility practices [48] |
| Child marriage [41,56] |
| Language spoken [32] |
| Cultural acceptance [23]/ Individual tolerance [23] |
| **3.3.Environment & seasonality** |
| **3.3.1Climate Variability & Extremes** |
| Climate vulnerability/change/warming/weather extremes [22,26,41] |
| Sea level rise, low-elevation coastal zones and losses of sustainable water sources [56] |
| Less-favoured agriculture areas [56] |
| Altitude [29] |
| Evapotranspiration [56] |
| Loss of forest cover [32] |
| High levels of air pollution [56]/ Higher carbon dioxide concentrations [56] |

# 5. Conclusions and implications

This study is the first component of a Research Study that aims to produce evidence to assist decision-makers in addressing the problem of persistent undernutrition in several areas of Sahelian countries, despite the significant concentration of regular and sustained nutrition programming over decades. It is based on a stepwise approach of three study components. Here, we present findings from the first component. We conducted a systematic mapping review of the literature to identify reported drivers of undernutrition in Sahelian countries and to critically discuss the representativeness and relevance of the drivers reported with the specificity of the region.

A list and citation frequency of the 76 identified drivers of undernutrition is provided, organised by undernutrition causes (immediate, underlying and basic/systemic), and respective dimensions, and contextualised in the Sahel according to outcomes and countries where each driver has been described. These findings suggest a potential bias in the publications towards immediate drivers of undernutrition, when compared to underlying and basic/systemic ones. The main findings indicate a limited evidence base on categories of drivers such as dietary intake, household food security and environment & seasonality, while disease, health & care environments, and the arrangement of formal and informal institutions are emphasised. This may reflect a higher attention given to the region by the health research community and the lack of local capacities to conduct research addressing the larger drivers of malnutrition, particularly the interlinked effects across long causal pathways. It is surprising due to the known poverty status of the populations, who rely on farming systems highly vulnerable due to harsh agroecological conditions, resulting in food insecurity and inadequate diets. The underrepresentation of food and farming systems related drivers may be due to lack of research on these topics or less nutrition programming dedicated to this.

We also provide a list of drivers of undernutrition described in other LMICs with severe undernutrition burdens which have not been described in countries in the Sahel. Collectively, we hypothesise that some drivers of undernutrition not reported in Sahelian contexts – individual or linked by linear or non-linear associations - may be explanatory of the phenomenon. If ignored in the region, it makes it challenging to target and assess nutrition interventions, hampering their success.

These results may provide insight into additional topics for future research and interventions. The aetiology of undernutrition is multifactorial, so it might be relevant to address undernutrition drivers in multiple policies and programmes across these countries, not only those that are nutrition-specific. Also, there was a high heterogeneity in available data between different countries, highlighting the importance of investing in nutrition research in Sahelian countries with fewer available resources. By using the best-fit approach to analyse the identified drivers, we propose an adjusted framework to the specific context of the Sahel. This drawing can be instrumental to guide specific interventions targeted to key dimensions of undernutrition, leveraging the probability of success in the region.

It should be noted that this report lists what is known, i.e., the drivers and their relative frequency mentioned in published works. The presented findings will be collectively discussed with a parallel list of drivers disclosed by machine learning algorithms, using available geocoded data on the region from multiple sources, including population surveys and satellite data, for instance. The hypothesis is that by comparing both lists, a new understanding of the lack of impact of previous support and novel approaches for monitoring and guide monitoring and nutrition programming in the Sahel can be advocated. Most importantly, one aims at capturing explanations in non-linear relationships between drivers and in complex interactions between them. Hence, the two components should not be taken independently. Finally, a third component conducted *in loco* with contextualise evidence with regional knowledge and link with the main areas supported by international cooperation embedded in nutrition programming. A complementary study relates to the analysis of design gaps in programming by EU and non-EU donors. The study is analysing the

extent to which the programming is integrated i.e., multisectoral and will throw light on the extent on emphasis on addressing food systems within the agriculture programme, rather than just focussing on nutrition from a health sector perspective.

## 6. References


1. Brunton G, Oliver S & Thomas J (2020) Innovations in framework synthesis as a systematic review method. *Res Synth Methods* **11**, 316–330. John Wiley & Sons, Ltd.

2. Carroll C, Booth A, Leaviss J, et al. (2013) "Best fit" framework synthesis: refining the method. *BMC Med Res Methodol* **13**, 37.

3. World Health Organization (2017) Global Nutrition Monitoring Framework: operational guidance for tracking progress in meeting targets for 2025. World Health Organization.

4. World Health Organization (2006) *WHO child growth standards: length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age: methods and development*. World Health Organization.

5. World Health Organization (2009) WHO child growth standards and the identification of severe acute malnutrition in infants and children: joint statement by the World Health Organization and the United Nations Children's Fund. World Health Organization.

6. World Health Organization (2023) Fact Sheet - Malnutrition. https://www.who.int/news-room/fact-sheets/detail/malnutrition (accessed February 2024).

7. World Health Organisation (2023) Malnutrition. Key facts. https://www.who.int/news-room/fact-sheets/detail/malnutrition (accessed January 2024).

8. World Health Organization (2011) *Haemoglobin concentrations for the diagnosis of anaemia and assessment of severity*. World Health Organization.

9. UNICEF (1990) *Strategy for improved nutrition of children and women in developing countries*. New York, NY, USA: .

10. UNICEF (2020) *United Nations Children's Fund. (UNICEF). Nutrition, for Every Child: UNICEF Nutrition Strategy 2020–2030*. New York, USA: .

11. Health C on SD of (2008) *Closing the gap in a generation: health equity through action on the social determinants of health: final report of the commission on social determinants of health*. World Health Organization.

12. Young H (2020) Nutrition in Africa's Drylands: A Conceptual Framework for Addressing Acute Malnutrition. *Feinstein International Center, Tufts University*.

13. Wells JCK, Briend A, Boyd EM, et al. (2019) Beyond wasted and stunted—a major shift to fight child undernutrition. *Lancet Child Adolesc Health* **3**, 831–834. Elsevier.

14. World Health Organization (2017) Nutrition in the WHO African region. World Health Organization. Regional Office for Africa.

15. UNICEF Regional Nutrition Working Group (2023) Advocacy Note Addressing malnutrition in West and Central Africa:Addressing underlying vulnerabilities and ensuring sustainable financing. .

16. Bhutta ZA, Das JK, Rizvi A, et al. (2013) Evidence-based interventions for improvement of maternal and child nutrition: what can be done and at what cost? *The Lancet* **382**, 452–477. Elsevier.

17. Victora CG, Adair L, Fall C, et al. (2008) Maternal and child undernutrition: consequences for adult health and human capital. *The Lancet* **371**, 340–357. Elsevier.

18. Victora CG, Christian P, Vidaletti LP, et al. (2021) Revisiting maternal and child undernutrition in low-income and middle-income countries: variable progress towards an unfinished agenda. *The Lancet* **397**, 1388–1399. Elsevier.

19. Galler JR, Bringas-Vega ML, Tang Q, et al. (2021) Neurodevelopmental effects of childhood malnutrition: A neuroimaging perspective. *Neuroimage* **231**, 117828.

20. FAO, IFAD, UNICEF, et al. (2022) *The State of Food Security and Nutrition in the World 2022. Repurposing food and agricultural policies to make healthy diets more affordable*. Rome.

21. Lachat C, Roberfroid D, Van den Briel N, et al. (2015) A decade of nutrition research in Africa: assessment of the evidence base and academic collaboration. *Public Health Nutr* **18**, 2014/10/07, 1890–1897. Cambridge University Press.

22. Salm L, Verstraeten R, Nisbett N, et al. (2021) Exploring the drivers of malnutrition in West Africa from health and social science perspectives: A comparative methodological review. *Method Innov* **14**, 20597991211051444. SAGE Publications Sage UK: London, England.

23. Adeoya AA, Sasaki H, Fuda M, et al. (2022) Child Nutrition in Disaster: A Scoping Review. *Tohoku J Exp Med* **256**, 103–118. Tohoku University Medical Press.

24. Marshall AI, Lasco G, Phaiyarom M, et al. (2021) Evidence on child nutrition recommendations and challenges in crisis settings: a scoping review. *Int J Environ Res Public Health* **18**, 6637. MDPI.

25. Millward DJ (2017) Nutrition, infection and stunting: the roles of deficiencies of individual nutrients and foods, and of inflammation, as determinants of reduced linear growth of children. *Nutr Res Rev* **30**, 50–72. Cambridge University Press.

26. Food Security Information Network (FSIN) (2022) *2022 Global report on food crises: Joint analysis for better decisions.* . Rome, Italy; and Washington, DC. : .

27. Griffiths JK & Kikafunda JK (2015) Childhood threats to adult cognition in sub-Saharan Africa: Malaria, anemia, stunting, enteric enteropathy, and the microbiome of malnutrition. *Brain degeneration and dementia in sub-Saharan Africa*, 75–87. Springer.

28. Aminin F, Damayanti M, Saputri NAS, et al. (2022) DETERMINANTS OF STUNTING: A SYSTEMATIC REVIEW. *International Journal of Social Science* **1**, 1065–1076.

29. Brown ME, Backer D, Billing T, et al. (2020) Empirical studies of factors associated with child malnutrition: highlighting the evidence about climate and conflict shocks. *Food Secur* **12**, 1241–1252. Springer.

30. WCA Regional Nutrition Working Group (2022) *Joint Note on the Nutrition Situation in the West and Central Africa Region*. .

31. Wirth JP, Rohner F, Petry N, et al. (2017) Assessment of the WHO Stunting Framework using Ethiopia as a case study. *Matern Child Nutr* **13**, e12310. Wiley Online Library.

32. Obasohan PE, Walters SJ, Jacques R, et al. (2020) Risk factors associated with malnutrition among children under-five years in sub-Saharan African countries: a scoping review. *Int J Environ Res Public Health* **17**, 8782. MDPI.

33. Lemoine A & Tounian P (2020) Childhood anemia and iron deficiency in sub-Saharan Africa–risk factors and prevention: A review. *Archives de Pédiatrie* **27**, 490–496. Elsevier.

34. Katoch OR (2022) Determinants of malnutrition among children: A systematic review. *Nutrition* **96**, 111565. Elsevier.

35. Geta TG, Gebremedhin S & Omigbodun AO (2022) Prevalence and predictors of anemia among pregnant women in Ethiopia: Systematic review and meta-analysis. *PLoS One* **17**, e0267005. Public Library of Science San Francisco, CA USA.

36. Kassebaum NJ & Collaborators GBD 2013 Anemia (2016) The global burden of anemia. *Hematol Oncol Clin North Am* **30**, 247–308. Elsevier.

37. Atanga RA & Tankpa V (2021) Climate change, flood disaster risk and food security Nexus in Northern Ghana. *Front Sustain Food Syst* **5**, 706721. Frontiers Media SA.

38. Domenech Descarrega L (2015) Is reliable water access the solution to undernutrition? A review of the potential of irrigation to solve nutrition and gender gaps in Africa South of the Sahara. *IFPRI Discussion Paper*. International Food Policy Research Institute.

39. CILSS (2022) *Rapport régional sur la sécurité alimentaire et nutritionnelle au Sahel et en Afrique de l'Ouest*.

40. Arthur SS, Nyide B, Soura AB, et al. (2015) Tackling malnutrition: a systematic review of 15-year research evidence from INDEPTH health and demographic surveillance systems. *Glob Health Action* **8**, 28298. Taylor & Francis.

41. Haile B, Azzarri C & Ahn HE (2021) Literature review on linkages between child nutrition and economic growth. Intl Food Policy Res Inst.

42. Corley AG (2021) Linking armed conflict to malnutrition during pregnancy, breastfeeding, and childhood. *Glob Food Sec* **29**, 100531. Elsevier.

43. Vaivada T, Akseer N, Akseer S, et al. (2020) Stunting in childhood: an overview of global burden, trends, determinants, and drivers of decline. *Am J Clin Nutr* **112**, 777S-791S. Oxford University Press.

44. Bourke CD, Jones KDJ & Prendergast AJ (2019) Current understanding of innate immune cell dysfunction in childhood undernutrition. *Front Immunol* **10**, 1728. Frontiers Media SA.

45. Bartlett S (2003) Water, sanitation and urban children: the need to go beyond "improved" provision. *Environ Urban* **15**, 57–70. Sage Publications Sage CA: Thousand Oaks, CA.

46. Prendergast AJ & Kelly P (2016) Interactions between intestinal pathogens, enteropathy and malnutrition in developing countries. *Curr Opin Infect Dis* **29**, 229. Wolters Kluwer Health.

47. Vilcins D, Sly PD & Jagals P (2018) Environmental risk factors associated with child stunting: a systematic review of the literature. *Ann Glob Health* **84**, 551. Ubiquity Press.

48. Reinhardt K & Fanzo J (2014) Addressing chronic malnutrition through multi-sectoral, sustainable approaches: a review of the causes and consequences. *Front Nutr* **1**, 13. Frontiers Media SA.

49. Chehab RF, Cross T-WL & Forman MR (2021) The gut microbiota: a promising target in the relation between complementary feeding and child undernutrition. *Advances in Nutrition* **12**, 969–979. Oxford University Press.

50. Harper KM, Mutasa M, Prendergast AJ, et al. (2018) Environmental enteric dysfunction pathways and child stunting: A systematic review. *PLoS Negl Trop Dis* **12**, e0006205. Public Library of Science San Francisco, CA USA.

51. Mackinnon E, Ayah R, Taylor R, et al. (2019) 21st century research in urban WASH and health in sub-Saharan Africa: methods and outcomes in transition. *Int J Environ Health Res* **29**, 457–478. Taylor & Francis.

52. Thurstans S, Sessions N, Dolan C, et al. (2022) The relationship between wasting and stunting in young children: A systematic review. *Matern Child Nutr* **18**, e13246. Wiley Online Library.

53. Lelijveld N, Stephenson K & Manary M (2022) Promoting linear growth when treating child wasting. *Field Exchange 67*, 70. Emergency Nutrition Network (ENN).

54. Vaivada T, Akseer N, Akseer S, et al. (2020) Stunting in childhood: an overview of global burden, trends, determinants, and drivers of decline. *Am J Clin Nutr* **112**, 777S-791S. Oxford University Press.

55. Owais A, Merritt C, Lee C, et al. (2021) Anemia among women of reproductive age: an overview of global burden, trends, determinants, and drivers of progress in low-and middle-income countries. *Nutrients* **13**, 2745. MDPI.

56. Helldén D, Andersson C, Nilsson M, et al. (2021) Climate change and child health: a scoping review and an expanded conceptual framework. *Lancet Planet Health* **5**, e164–e175. Elsevier.

57. Maulina R, Qomaruddin MB, Sumarmi S, et al. (2022) Antenatal Depression as a Stunting Risk Factor: A Systematic Review. *Open Access Maced J Med Sci* **10**, 234–240.

58. Keino S, Plasqui G, Ettyang G, et al. (2014) Determinants of stunting and overweight among young children and adolescents in sub-Saharan Africa. *Food Nutr Bull* **35**, 167–178. SAGE Publications Sage CA: Los Angeles, CA.

59. Bhutta ZA, Akseer N, Keats EC, et al. (2020) How countries can reduce child stunting at scale: lessons from exemplar countries. *Am J Clin Nutr* **112**, 894S-904S. Oxford University Press.

60. Abate KH & Belachew T (2019) Chronic malnutrition among under five children of Ethiopia may not be economic. A systematic review and meta-analysis. *Ethiop J Health Sci* **29**.

61. Simwanza NR, Kalungwe M, Karonga T, et al. (2023) Exploring the risk factors of child malnutrition in Sub-Sahara Africa: a scoping review. *Nutr Health* **29**, 61–69. SAGE Publications Sage UK: London, England.

62. Tadesse SE, Zerga AA, Mekonnen TC, et al. (2022) Burden and Determinants of Anemia among Under-Five Children in Africa: Systematic Review and Meta-Analysis. *Anemia* **2022**. Hindawi Limited.

63. Thurstans S, Opondo C, Seal A, et al. (2020) Boys are more likely to be undernourished than girls: a systematic review and meta-analysis of sex differences in undernutrition. *BMJ Glob Health* **5**, e004030.

64. Mardani RAD, Wu W, Nhi VT, et al. (2022) Association of breastfeeding with undernutrition among children under 5 years of age in developing countries: A systematic review and meta-analysis. *Journal of Nursing Scholarship* **54**, 692–703. Wiley Online Library.

65. Ode D, Murti B & Budihastuti UR (2022) Correlation between Low Birth Weigth and Stunting in Children Under Five: Meta Analysis. *Journal of Maternal and Child Health* **7**, 498–509.

66. Lawn JE, Blencowe H, Oza S, et al. (2014) Every Newborn: progress, priorities, and potential beyond survival. *The lancet* **384**, 189–205. Elsevier.

67. Hlimi T (2015) Association of anemia, pre-eclampsia and eclampsia with seasonality: a realist systematic review. *Health Place* **31**, 180–192. Elsevier.

68. Wrottesley S V, Lamper C & Pisa PT (2016) Review of the importance of nutrition during the first 1000 days: maternal nutritional status and its associations with fetal growth and birth, neonatal and infant outcomes among African women. *J Dev Orig Health Dis* **7**, 144–162. Cambridge University Press.

69. Kennedy E, Jafari A, Stamoulis KG, et al. (2020) The first Programmefood and nutrition security, impact, resilience, sustainability and transformation: Review and future directions. *Glob Food Sec* **26**, 100422. Elsevier.

70. Akseer N, Kandru G, Keats EC, et al. (2020) COVID-19 pandemic and mitigation strategies: implications for maternal and child health and nutrition. *Am J Clin Nutr* **112**, 251–256. Oxford University Press.

71. Gassara G & Chen J (2021) Household food insecurity, dietary diversity, and stunting in sub-saharan africa: a systematic review. *Nutrients* **13**, 4401. MDPI.

72. Maitra C (2018) *review of studies examining the link between food insecurity and malnutrition*. FAO.

73. Cusick SE & Kuch AE (2012) Determinants of undernutrition and overnutrition among adolescents in developing countries. *Adolesc Med State Art Rev* **23**, 440. NIH Public Access.

74. Haile B, Azzarri C & Ahn HE (2021) Literature review on linkages between child nutrition and economic growth. Intl Food Policy Res Inst.

75. Rachmayanti RD, Kevaladandra Z, Ibnu F, et al. Systematic Review: Protective Factors from the Risks of Stunting in Breastfeeding Period. *Jurnal Promosi Kesehatan Indonesia* **17**, 72–78. Master Program of Health Promotion Faculty of Public Health Diponegoro ….

76. Fellmeth G, Rose-Clarke K, Zhao C, et al. (2018) Health impacts of parental migration on left-behind children and adolescents: a systematic review and meta-analysis. *The Lancet* **392**, 2567–2582. Elsevier.

77. Rosinger AY & Young SL (2020) The toll of household water insecurity on health and human biology: Current understandings and future directions. *WIREs Water* **7**, e1468. John Wiley & Sons, Ltd.

78. Odo DB, Yang IA & Knibbs LD (2021) A Systematic Review and Appraisal of Epidemiological Studies on Household Fuel Use and Its Health Effects Using Demographic and Health Surveys. *Int. J. Environ. Res. Public Health* **18**, 1411.

79. Kamal A, Cincinelli A, Martellini T, et al. (2015) A review of PAH exposure from the combustion of biomass fuel and their less surveyed effect on the blood parameters. *Environmental Science and Pollution Research* **22**, 4076–4098.

80. Cardwell KF & Henry SH (2004) Risk of Exposure to and Mitigation of Effect of Aflatoxin on Human Health: A West African Example. *J Toxicol Toxin Rev* **23**, 217–247. Taylor & Francis.

81. Smith LE, Prendergast AJ, Turner PC, et al. (2017) Aflatoxin exposure during pregnancy, maternal anemia, and adverse birth outcomes. *Am J Trop Med Hyg* **96**, 770. The American Society of Tropical Medicine and Hygiene.

82. Alfani F, Dabalen A, Fisker P, et al. (2015) *Vulnerability to Malnutrition in the West African Sahel*. *Policy Research Working Papers*. The World Bank.

83. Bhutta ZA, Ahmed T, Black RE, et al. (2008) What works? Interventions for maternal and child undernutrition and survival. *The lancet* **371**, 417–440. Elsevier.

84. Bendavid E, Boerma T, Akseer N, et al. (2021) The effects of armed conflict on the health of women and children. *The Lancet* **397**, 522–532. Elsevier.

85. Sassi M & Thakare H (2022) Conflict and Child Malnutrition: a Systematic Review of the Emerging Quantitative Literature. *Curr Nutr Rep* **11**, 1–8. Springer.

86. Pennington A, Orton L, Nayak S, et al. (2018) The health impacts of women's low control in their living environment: a theory-based systematic review of observational studies in societies with profound gender discrimination. *Health Place* **51**, 1–10. Elsevier.

87. Pratley P (2016) Associations between quantitative measures of women's empowerment and access to care and health status for mothers and their children: a systematic review of evidence from the developing world. *Soc Sci Med* **169**, 119–131. Elsevier.

88. Margatot DI & Huriah T (2021) The effectiveness of women empowerment in preventing stunting in children aged 6-59 months. *Bali Medical Journal* **10**, 1230–1234.

89. Annisa L & Sulistyaningsih S (2022) The Empowerment of Family in Effort to Reduce Stunting in Under-Five Children: A Scoping Review. *Jurnal Aisyah: Jurnal Ilmu Kesehatan* **7**, 451–460.

90. Unicef (2015) *The challenges of climate change: children on the front line*. eSocialSciences.

91. Sheehan MC (2022) 2021 Climate and Health Review–Uncharted Territory: Extreme Weather Events and Morbidity. *International Journal of Health Services* **52**, 189–200. SAGE Publications Sage CA: Los Angeles, CA.

92. Gol RM, Kheirouri S & Alizadeh M (2022) Association of dietary diversity with growth outcomes in infants and children aged under 5 years: a systematic review. *J Nutr Educ Behav* **54**, 65–83. Elsevier.

93. SWAC/OECD (2021) *Food system transformations in the Sahel and West Africa: implications for people and policies , Maps & Facts, no. 4*. .

94. Jidong DE, Husain N, Ike TJ, et al. (2021) Maternal mental health and child well-being in Nigeria: A systematic review. *Health Psychol Open* **8**, 20551029211012200. SAGE Publications Sage UK: London, England.

95. Allan-Blitz L-T, Goldfine C & Erickson TB (2022) Environmental and health risks posed to children by artisanal gold mining: A systematic review. *SAGE Open Med* **10**, 20503121221076936. SAGE Publications Sage UK: London, England.

96. SCHELLING E., GRETER H., KESSELY H., et al. (2016) Human and animal health surveys among pastoralists. *Scientific & Technical Review* **35**, 659–671.

# Annex 1. Concepts and definitions

**"Best-fit" framework-synthesis systematic review:** a mixed-methods type of systematic review that uses a deductive approach of mapping data from primary research studies onto a predefined framework (*a priori* framework), which represents the theoretical background of the issue under study [1,2]. As new data are incorporated and themes are derived, the framework is updated, resulting in the final framework being a mix of initial and revised themes [1]. This approach produces a rapid, transparent and pragmatic process of synthesis: a substantial amount of the data to be included in the review is often coded against the *a priori* framework and only the data that cannot be accommodated within the framework requires iterative interpretation using inductive, thematic analysis techniques [2].

**Framework synthesis:** a structured approach to organizing and analysing the data, involving the preliminary identification of a priori dimensions against which to map data from included studies and eventually the emergence of new dimensions/concepts [2].

**Undernutrition outcomes:** primary outcomes were considered any form of undernutrition among children, such as stunting, wasting, underweight, malnutrition or anaemia, or anaemia among women of reproductive age. Detailed definitions and indicators are described in table S1.

***Table S1.*** *Definitions of outcome indicators, as used throughout the systematic review.*

| Outcome Indicator | Definition / measurement |
|---|---|
| **Stunted** [3,4] | Stunting is a process of linear growth failure due to inadequate nutrition over a prolonged period of time and is worsened by recurrent and chronic illness and psychosocial inadequacies.<br>Stunting was defined as a height/length-for-age z score below two standard deviations (-2 SD) from the median of the World Health Organisation (WHO) Child Growth Standards. If a child is below minus three standard deviations (-3 SD) from the median of the WHO Child Growth Standards, then he/she is considered to be severely stunted. |
| **Wasted** [3–5] | Wasting reflects a process of weight loss due to an acute or recent nutritional deficit, although it can also persist for a long time. It usually occurs when a person has not had food of adequate quality and quantity and/or they have had frequent or prolonged illnesses. Wasting is often referred to as acute malnutrition (AM) or global acute malnutrition (GAM).<br>Wasting was defined as a weight-for-height/length z score below two standard deviations (-2 SD) from the median of the WHO Child Growth Standards.<br>Mid-upper arm circumference (MUAC) can be used as a rapid screening tool in resource-limited countries to identify wasting in children aged 6-59 months. WHO recommends using either or both weight-for-height/length z score or MUAC and the presence of nutritional oedema to assess the prevalence of acute malnutrition and for admission and graduation criteria for treatment programs [5]. MUAC measures the muscle mass of the upper arm. A flexible measuring tape is wrapped around the mid-upper arm (between the shoulder and elbow) to measure its circumference. MUAC should be measured to the nearest 0.1 cm. |
| **Underweight** [7] | A child who is underweight may be stunted, wasted, or both.<br>Underweight was defined as a weight-for-age z score below two standard deviations (-2 SD) from the median of the WHO Child Growth Standards [7]. |

| | |
|---|---|
| **Undernutrition** [7] | A group of conditions that includes wasting, stunting, underweight and deficiencies in vitamins and minerals. Undernutrition makes children in particular much more vulnerable to disease and death [7]. |
| **Malnutrition** [6] | Malnutrition refers to deficiencies, excesses, or imbalances in a person's intake of energy and/or nutrients. The term malnutrition addresses three broad groups of conditions: Undernutrition, Micronutrient-related Malnutrition (which includes micronutrient deficiencies - a lack of important vitamins and minerals - or micronutrient excess); and overweight, obesity and diet-related noncommunicable diseases (such as heart disease, stroke, diabetes and some cancers)[6]. |
| **Anaemia** [3,8] | Anaemia is defined as a haemoglobin concentration below a specified cut-off point. The cut-off point depends on the age, sex, physiological status, smoking habits and altitude at which the population being assessed lives.<br><br>Anaemia **in children 6–59 months** is defined as a haemoglobin concentration <110 g/L at sea level, moderate anaemia of haemoglobin 70–99 g/L and severe anaemia of haemoglobin < 70 g/L.<br><br>Anaemia **in women** is defined as a haemoglobin concentration <110 g/L at sea level, and in non-pregnant women as a haemoglobin concentration <120 g/L. |

**UNICEF/Young framework of undernutrition:** most frameworks illustrating the drivers of undernutrition derive from the "UNICEF conceptual framework of undernutrition," first developed in 1990 and regularly updated [8,9]. It was also adopted by the WHO[10]. This framework acknowledges the causality of undernutrition at the micro (individual or household) and macro levels (local communities and society). The immediate causes of malnutrition capture the physiological reasons why an individual child becomes malnourished (related to food intake and disease). These reasons are driven by the underlying causes (inadequate household food security, care of women and children, and the health environment and access to health care), which are determined by the basic causes of malnutrition. In the original UNICEF conceptual framework, the basic causes were primarily focused on "resources" (human, financial, and organizational), being the key determinants of reaching adequacy in the underlying causes [9–11]

An updated version of this framework was proposed by Young et al. [12], by adding dimensions related to characteristics of acute malnutrition in Africa's drylands (covering countries in the Sahel and West Africa) [12]. To account for these phenomena, the framework of *acute malnutrition in Africa's drylands* includes systemic dimensions such as, *inter alia*, gender, livelihoods, and environment and seasonality (Figure S1). Despite the framework focuses on acute malnutrition (wasting), it was considered to be adequate given that according to prior literature, drivers of stunting and wasting tend to be derived from the same causes (*i.e.*, conceptual dimensions) [13].

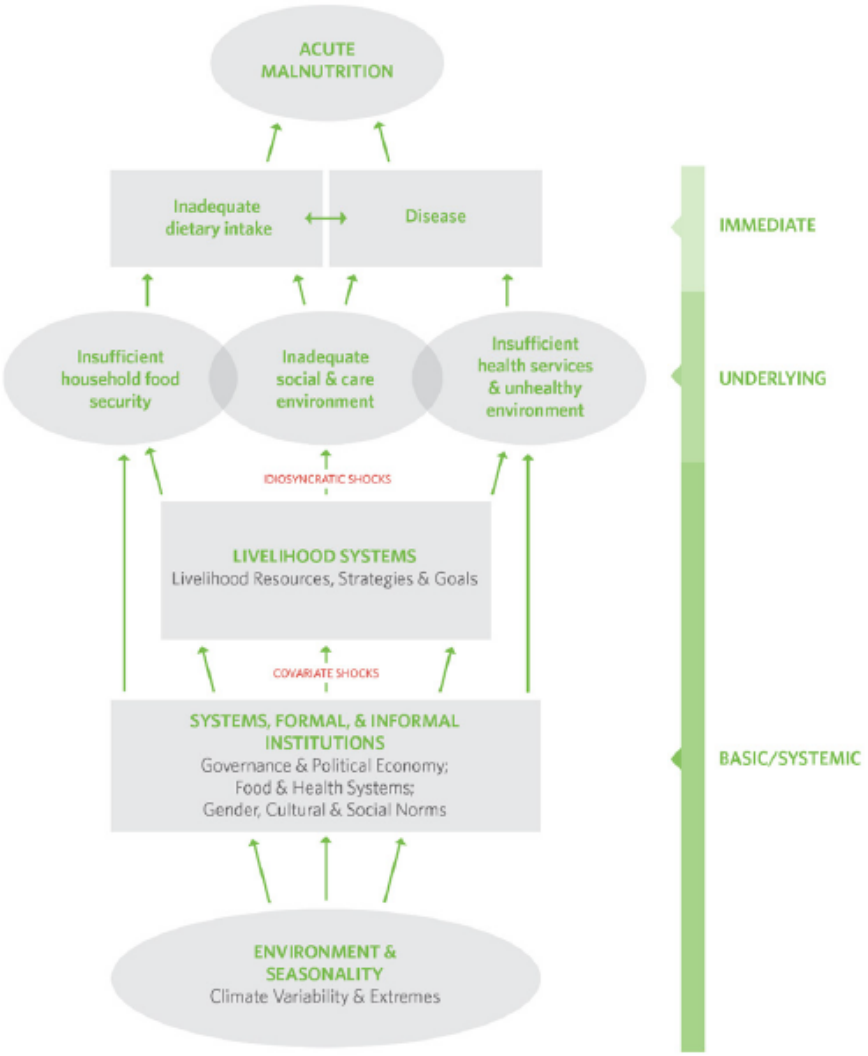



***Figure S1050.****Conceptual framework for the explanation of acute malnutrition in Africa's drylands. Source: Young, 2020.*

# Annex 2. Summary description of included studies

***Table S2.*** *Summary characteristics of the studies included in the systematic review (n=72).*

| Author | Year | Publication type | Type of review | Population | Outcome(s) | Setting | Drivers |
|---|---|---|---|---|---|---|---|
| Abate, K. H. | 2019 | Scientific paper | Systematic Review | Children | Stunting; wasting | Only countries in the Sahel | Predictors of stunting: non-adherence towards optimal feeding recommendations of WHO; maternal education. Among biologic factors, Child's age and child's sex; Morbidity, optimal health care practice by the mother or the child (immunisation, deworming, antenatal care, family planning) were also reported. Residence (urban versus rural) is the most reported socio-demographic variable (n=9 studies) while 'Water, Sanitation and Hygiene' (WASH) factors were reported by five authors predicting stunting. Morbidity (fever, diarrhoea, ARI) was also reported. predictor of stunting. Food insecurity. Predictors of wasting: non-adherence towards Optimal feeding recommendations of WHO; "Water, Sanitation and Hygiene" factors (n=10 studies), maternal education; Child's age and child Sex; morbidity, optimal health care practice by the mother or the child (immunisation, antenatal care and family planning). Residence and family size; food insecurity. |
| Adeoya, AA | 2022 | Scientific paper | (Systematic) Scoping review | Children | Stunting; wasting | LMIC, including in the Sahel | Disaster is a driver of child stunting, wasting, micronutrient deficiencies (kwashiorkor), through: communicable diseases, food allergy, inadequate diet quality and quantity - food aid low in protein and vitamins, food safety, food insecurity, breastfeeding practices, insufficient offer of infant-feeding products, stress and psychological trauma at the household level, hygienic conditions; policy level - emergency preparedness; ; socio-cultural factors: Misconceptions, cultural practices, and other beliefs drive inadequate behaviours such as Child feeding practices and other household health, agriculture, and WASH behaviours; handling properties, preparation ease, religious and cultural acceptance, and individual tolerance; age, ethnic, and religious groups; the general food rations should satisfy not only the population's nutritional requirements but also qualitative criteria of cultural acceptability, safety, digestibility, and ease of preparation and storage; emergency foods should reflect formulas and special foods for emergencies, food diversity, nutritional needs of different groups, food health and safety, and functional features such as packaging, cultural norms, and final price.; Widespread poverty, insecurity, and poor health care are major triggers for child malnutrition; the traditional diet of Rwandans as causing vitamin A deficiency and high rates of anaemia that are endemic in Rwanda.; disaster in low-income countries are more likely to lead |

| Author | Year | Publication type | Type of review | Population | Outcome(s) | Setting | Drivers |
|---|---|---|---|---|---|---|---|
| | | | | | | | to higher morbidity and mortality than disaster striking middle income and high-income countries because of higher vulnerabilities of the population, weaker healthcare systems, and limited surge capacity.; younger children are more vulnerable; food insecurity; Conflict often leads to disruption of crop production, destruction of food stores and livestock, compulsion of people to eat foods with lower nutritional value, disruption of market food supplies and price inflation, compulsion of people to live in unhealthy environments, degradation of health services, and degradation of productivity and family care structures.; Children's vulnerability is increased when they are separated from their families, unaccompanied, orphaned, or displaced following a disaster: living in evacuation shelters of temporary housing.; absence of an emergency food distribution program and lack of food diversification up to several weeks following the disaster. |
| Akseer, N. | 2020 | Scientific paper | Narrative review | Children | Stunting; wasting | LMIC, including in the Sahel | Risk Factors for Undernutrition in the Context of COVID-19: *Food insecurity and poor-feeding practices (*Limited or interrupted food supply chain, driving food insecurity, *Interrupted school & community nutrition programming /counselling); • Reduced income and limited financial resources (*Increased poverty and reduced spending power, *Limited / interrupted social safety nets, *Interrupted / discontinued education); • Limited care and restricted health services (* Reduced care seeking, *Limited access to modern contraceptives and family planning – driving high-risk pregnancies, *Reduced coverage of antenatal care services, *Limited service and supplies for regular maternal and childcare delivery e.g. immunisations); • Interrupted education for children and adults; • Unhealthy household environment (*Limited access / proximity to available services, e.g., clean water, safe sanitation); Deprioritised context and compromised enablers (*Policy diversion to urgent care, *Reduced social sector spending or diversion to COVID response, *Increased inequity). |
| Alfani, F. | 2015 | Technical/discussion paper | Narrative review | Children | Malnutrition/ undernutrition | Only countries in the Sahel | RISK CONTEXT OF THE SAHEL: diminish human capital of the households; physical destruction of human capital happens when there is a large-scale conflict or high mortality epidemic - pests, droughts and floods, when they destroy crops and livestock assets. rainfall failure. The drying of the Sahel, and subsequent changes to social organisations and livelihoods, (...). price shocks (...) for many of the countries, price volatility is remarkably high and highly correlated with the growing season (...). Communal conflict (...) political instability, characterised by coups and low scale violence. |

| Author | Year | Publication type | Type of review | Population | Outcome(s) | Setting | Drivers |
|---|---|---|---|---|---|---|---|
| Allan-Blitz, L.-T. | 2022 | Scientific paper | Systematic Review | Children | Malnutrition/ undernutrition; anaemia | LMIC, including in the Sahel | the occupational hazards noted among children included work-related malnutrition. (…) Lead was the most identified exposure among children. The consequences of lead (...) anaemia, worse birth outcomes (…). |
| Aminin, F. | 2022 | Scientific paper | Systematic Review | Children | Stunting | LMIC, including in the Sahel | Drivers of undernutrition: non-exclusive breastfeeding; low socioeconomic status of the household; low birth weight, premature birth, short birth length and low maternal education; children living in villages, in slum households, sanitation bad environment, culture is a risk factors for stunting in children; mothers correctly assessing the child nutrition status were less likely to have stunted children than those who did not assess this correctly. (...) Culture in child feeding covers the mothers' belief in feeding, child feeding practices, and child's eating habits. Socio-cultural practices and beliefs had been shown to influence the feeding of children, thus determining their nutritional status. Significant relationships between energy intake level, history of infectious disease duration with the incidence of stunting. Exclusive breastfeeding is strongly associated with reducing the risk of stunting . |
| Annisa, L. | 2022 | Scientific paper | (Systematic) Scoping review | Children | Stunting | LMIC, including in the Sahel | Mothers' decision making in the household, education, and environment are considered significant aspects in family empowerment, and they are expected to make changes, improve mothers' knowledge and skills in child nutritional intake as the effort of stunting decrease |
| Arthur, S.S. | 2015 | Scientific paper | Systematic Review | Children | Malnutrition/ undernutrition | LMIC, including in the Sahel | Urbanisation is protective against under-nutrition. Appropriately timed breastfeeding interventions were protective against malnutrition |
| Atanga, RA | 2021 | Scientific paper | (Systematic) Scoping review | Children | Malnutrition/ undernutrition | Only countries in the Sahel | Excessive rainfall can increase the risk of infectious diseases such as malarial, parasitic, and diarrheal disease, in turn harming proper food utilisation and increasing rates of undernutrition. While rates of undernutrition and food insecurity have been falling overall for the past few decades, there have been recent increases in these statistics in some locations, which is attributable to flood shocks. With the increasing frequency of flood associated with climate change, agricultural production will decline to result in a decreased state of food production with high malnutrition. Climate change impacts are seen in droughts, rainfall variability and frequent flood events in the region. Flood disasters affect food availability, access, utility and stability in the region as food insecurity seems to be a widespread problem. Climate change and flood events are on the increase and could potentially deteriorate the undesired food security problems in the region if not addressed. |

| Author | Year | Publication type | Type of review | Population | Outcome(s) | Setting | Drivers |
|---|---|---|---|---|---|---|---|
| Bartlett, S. | 2003 | Scientific paper | Narrative review | Children | Undernutrition | African countries, including in the Sahel | Diarrhoea, intestinal parasites, unsanitary environments; level of access to water |
| Bendavid, E. | 2021 | Scientific paper | Narrative review | Children | Undernutrition | LMIC, including in the Sahel | Protracted armed conflicts; conflict-affected countries had higher levels of wasting in under-fives than the sub-regional averages for the same year during the conflict phase (1·0% higher) but had lower prevalence in surveys conducted 0–4 years (1·2% lower) and 5–9 years (2·2% lower) after the end of the conflict. stunting in children born near a conflict was 2·9% higher than the 34·4% average prevalence. |
| Bhutta, Z. A. | 2020 | Scientific paper | Systematic Review | Children | Stunting; wasting; anaemia | LMIC, including in the Sahel | Improvements in maternal education, maternal nutrition, maternal and newborn care, and reductions in fertility/reduced interpregnancy intervals (…). Countries made progress through interventions from within (50%) and outside the health sector (40%). new evidence has been generated, including the impacts of lipid-nutrient supplements on stunting, wasting, anaemia. Determinants of particular importance were improved parental literacy rates, household socioeconomic status, water, sanitation, and hygiene (WASH) conditions, health services access, and family planning. (...) gains in overall development, employment, literacy, female empowerment, household conditions, health and out-of-pocket spending, health worker availability, and maternal and child health (among other indicators) have been observed. (...) child gender (...). Notably, improvements in maternal education, maternal and newborn health care, reduction in fertility/reduced interpregnancy intervals, and maternal nutritional status were strong and common contributors to mean HAZ gains across most countries. reduced open defecation (...) improved WASH practices (...) increased consumable crop yield (...) mountainous population migration (...) household food security. Effective initiatives included health and nutrition interventions addressing immediate determinants that could be grouped into those to improve maternal nutrition and newborn outcomes, promote early and exclusive breastfeeding, and improve complementary feeding practices. investments in improving reproductive health practices were important for increasing contraceptive use, delaying first pregnancy, and increasing birth spacing. Other sectoral strategies, such as those to improve economic conditions, parental education, and WASH, |

| Author | Year | Publication type | Type of review | Population | Outcome(s) | Setting | Drivers |
|---|---|---|---|---|---|---|---|
| Bhutta, Z.A. | 2008 | Scientific paper | Systematic Review | Children | Stunting; Malnutrition/ undernutrition | LMIC, including in the Sahel | *Counselling about breastfeeding and fortification or supplementation with vitamin A and zinc have the greatest potential to reduce the burden of child morbidity and mortality; *Improvement of complementary feeding through strategies such as counselling about nutrition for food-secure populations and nutrition counselling, food supplements, conditional cash transfers, or a combination of these, in food-insecure populations could substantially reduce stunting and related burden of disease; *Interventions for maternal nutrition (supplements of iron folate, multiple micronutrients, calcium, and balanced energy and protein) can improve outcomes for maternal health and births, but few have been assessed at sufficient scale; +: *Underlying determinants of undernutrition: poverty, poor education, disease burden, and lack of women's empowerment. |
| Bourke, C. D. | 2019 | Scientific paper | Narrative review | Children | Undernutrition | LMIC, including in the Sahel | Inflammatory biomarkers/infection/EED.(...) Not all children with environmental enteric dysfunction (EED) are malnourished, however reduced gut surface area and function due to EED may function as a barrier to healthy nutrition among children with an adequate nutrient intake and during therapeutic feeding of children who are already stunted and/or wasted. A systematic review of the hypothesised pathways linking EED and stunting found evidence that intestinal inflammation is associated with systemic inflammation and reduced linear growth |
| Brown, M. E. | 2020 | Scientific paper | Systematic Review | Children | Stunting; wasting; underweight | LMIC, including in the Sahel | Risk factors: male sex (W, S), age (W, S, U), birth order (S), multiple birth (W,S,U), short birth interval (S), diarrhoea (W), rural residence (W, U), indigenous (S), Altitude (S), excessive rainfall (w), extreme temperature (S), drought (U), conflict in region (U), born during conflict (U), conflict exposure (days/months) (U). Mitigating factors: professional birth (S), vitamin A supplements (S), maternal education (W, S, U), paternal education (S), maternal BMI (W, S, U); maternal height (s), pregnancy care (s), wealth/assets (w, s, u), household materials quality (S), toilet (u), health centre access (w), food aid/supplemental feeding (s), growing season rainfall (w), gpd per capita (w, s, u), female to male life expectancy (u), female education (w, u), dietary energy supply per capita (u) |
| Cardwel, K.F. | 2004 | Scientific paper | Narrative review | Children | Stunting; underweight | LMIC, including in the Sahel | Aflatoxin exposure. Children with stunting or who were underweight had 30–40% higher mean AF-alb concentrations. The negative correlation between individual AF-alb concentration and each of the three growth parameters (height for age z score, weight for age z score, and weight for height z score) was highly significant. In rural Gambia, season can strongly influence both adult and children's nutritional status. |

| Author | Year | Publication type | Type of review | Population | Outcome(s) | Setting | Drivers |
|---|---|---|---|---|---|---|---|
| Chehab, R. F. | 2021 | Scientific paper | Systematic Review | Children | Undernutrition | LMIC, including in the Sahel | Inadequate Complementary feeding; disrupted gut microbiota |
| CILSS/AGRHYMET | 2022 | Technical report/publication | Narrative review | Children | Undernutrition | Only countries in the Sahel | Access to health and hygiene services and drinking water were also identified as major factors impacting the nutritional status of children under five (...). However, in the region, many health centres are still closed due to civil insecurity. Added to this is the high prevalence of childhood illnesses (particularly malaria, diarrhoea and acute respiratory infections) and a resurgence of measles epidemics in Côte d'Ivoire, Mali and Nigeria, which are also causes of the high prevalence of child malnutrition. |
| Corley, A. G. | 2021 | Scientific paper | Systematic Review | Children | Stunting; underweight | LMIC, including in the Sahel | Armed conflicts' (systems, formal & informal institutions - basic drivers) drivers of malnutrition: Immediate - Disease (infection/malabsorption malnutrition); Underlying - Insufficient household food security (destruction of agriculture and persistent insecurity; foreign economic embargos; loss of family providers; food as a weapon of war); inadequate social & care environment (maternal stress; insufficient health services & unhealthy environment (stress of displacement) |
| Cusick, S. E. | 2012 | Scientific paper | Narrative review | WRA | Anaemia | LMIC, including in the Sahel | Iron deficiency; access to iron supplementation; access to multiple micronutrient supplementation |
| Domènech, L. | 2015 | Technical/discussion paper | Systematic Review | Children | Stunting; wasting; underweight; undernutrition | LMIC, including in the Sahel | Significantly higher HAZ (height-for-age Z-score) was estimated among higher-income households with irrigation, and significantly higher WAZ (weight-for-age Z-score) was estimated among commercial households with irrigation in comparison to equivalent groups without irrigation. These results suggest that enhanced food production as a result of irrigation leads to higher food availability and improved nutritional status, but results are not conclusive. A seasonal comparison of the nutritional status of children and their mothers in areas with and without irrigation was conducted in the Gambia - Higher levels of stunting and wasting were found in the group of children without access to irrigation. However, underweight prevalence was higher among the group of children with access to irrigation. Seasonally, prevalence of undernutrition was higher in the wet season, when food supplies are lower; this effect was more significant for wasting, as weight-for-height values reflect the short-term (acute) nutritional situation. In line with these results, weight fluctuations between the wet and dry season were smaller among women who benefited from irrigation, suggesting that seasonal imbalances between energy intake and energy expenditure were also smaller among these women. Besides lack of food, in a multivariate analysis unclean water and infectious diseases were identified as important determinants of undernutrition. High prevalence of diarrhoea was |

| Author | Year | Publication type | Type of review | Population | Outcome(s) | Setting | Drivers |
|---|---|---|---|---|---|---|---|
| | | | | | | | associated with lower height-for-age and weight-for-age; however, the relationship was not significant for weight-for-height. The authors concluded that the prevalence of diarrhoea was an indicator of unhygienic conditions in the home, with important effects on the long-term (chronic) nutritional situation. |
| Fellmeth, G. | 2018 | Scientific paper | Systematic Review | Children | Stunting; wasting | LMIC, including in the Sahel | Compared with children of non-migrants, left-behind children had increased risk of wasting (RR 1·13 [1·02–1·24]) and stunting (RR 1·12 [1·00–1·26]). |
| FSIN (Food Security Information Network) | 2022 | Technical report/publication | Narrative review | Children | Stunting; wasting; Malnutrition/ undernutrition | LMIC, including in the Sahel | Determinants of malnutrition in emergency settings: displaced families residing in camps, disruptions to food, health, water and sanitation, and social protection systems render it more difficult for nutritionally vulnerable women and children to access healthy diets and health services, and to practise protective behaviours, such as breastfeeding. Conflict, low household purchasing power and weather extremes negatively affect access to adequate food and nutritionally diverse diets, essential services, and a safe and healthy environment, further exacerbating poor nutrition outcomes. Food supply chains and food environments are also often disrupted in emergencies, reducing household access to adequate nutritious foods and further contributing to challenges of nutrition vulnerability.<br>The intensification of conflicts in 2021, particularly in the Sahel, (...) has contributed to extremely high levels of wasting through increased displacement and disruptions to livelihoods, which adversely affected access to nutritional diets and health services. Weather-related shocks, such as drought (...) contributed further to child wasting by wiping out harvests and contributing to rising food prices and falling incomes, which hampered people's access to healthy diets, while also limiting access to safe drinking water and sanitation. The COVID-19 pandemic had a major impact on nutritional outcomes, as reduced incomes forced vulnerable families to rely on nutrient-poor staples. Movement restrictions and a reduction in the supply and availability of medicines due to logistical constraints disrupted access to services including the early detection and treatment of wasting, as well as support for breastfeeding and other recommended feeding and care practices for young children. Drivers of Nutrition Challenges (Sahel): Food security and access to healthy diets - High levels of acute food insecurity were a major contributing factor to the deteriorating nutritional status of children and women in Burkina Faso, Cameroon, Chad, Mali, the Niger and Nigeria, where conflicts and insecurity have triggered mass population displacements, disrupting access to food |

| Author | Year | Publication type | Type of review | Population | Outcome(s) | Setting | Drivers |
|---|---|---|---|---|---|---|---|
| | | | | | | | sources, livelihoods and essential services, decreasing production, pushing up food prices and often hindering the distribution of humanitarian food assistance. In areas hosting IDPs, such as Far-North, Littoral and West regions of Cameroon, the nutrition situation was concerning due to increased demand on limited food stocks. Health services and household environment - The multiple conflicts across the region – in addition to the economic crises and the impacts of COVID-19 – are preventing a rising number of households and communities from accessing basic social services, healthcare, sanitation, safe drinking water and hygiene, particularly those hosting IDPs. Millions of people in the Central Sahel have no access to medical care with health centres shut while most of the ones still open are not fully functional. A high prevalence of childhood diseases (particularly malaria, diarrhoea and acute respiratory infections) and a resurgence of measles outbreaks in Côte d'Ivoire, Mali and Nigeria are also driving the high prevalence of child malnutrition (CDC, March 2022). Care and feeding practices - Besides lack of access to healthy diets, cultural taboos relating to food choices also underlie poor food consumption patterns, inadequate child-feeding practices and low breastfeeding rates. The percentage of children aged 6–23 months who are fed the minimum acceptable diet (MAD) is as low as 9 percent in Chad, 10.5 percent in Mali, and 18 percent in Nigeria. In four out of eight regions in the Niger, fewer than a quarter of children receive the MAD, reaching just 3.6 percent in Dosso. The lack of adequate childcare for orphaned, abandoned and separated children is a major contributor to acute malnutrition. Anaemia among women of reproductive age is a public health concern in the region, with the prevalence above 40 percent, except in Libya (30 percent) and in Côte d'Ivoire, where no data were available. The situation is particularly poor in Benin, Mali and Nigeria where more than 55 percent of women are anaemic. |
| Gassara, G. | 2021 | Scientific paper | Systematic Review | Children | Stunting | LMIC, including in the Sahel | stunting was linked to household food insecurity and dietary diversity. |
| Geta, T. G. | 2022 | Scientific paper | Systematic Review | WRA | Anaemia | Only countries in the Sahel | Lower risk: urban residence, formal education and smaller family size. Higher risk: short birth interval, not having antenatal care, low dietary diversity, mid-upper arm circumference (MUAC) <23 cm, not taking iron-folic acid. |
| Gol, R.M. | 2021 | Scientific paper | Systematic Review | Children | Stunting | LMIC, including in the Sahel | Possible association between low dietary diversity of infants and children aged <5 years with stunting. |

| Author | Year | Publication type | Type of review | Population | Outcome(s) | Setting | Drivers |
|---|---|---|---|---|---|---|---|
| Griffiths, J.K. | 2015 | Book Chapter | Narrative review | Children | Stunting; wasting; underweight, anaemia | African countries, including in the Sahel | Risk factors for stunting (...) – undernutrition of the pregnant mother; inadequately nutritious diets; a lack of exclusive breast feeding and socio-economic status and wealth; poor water and sanitation; and many other factors (...); gut microbiota; (...). Maternal height is inversely associated with (...) stunting, underweight and wasting (...). Maternal overweight and obesity appear linked to early childhood undernutrition (...). The single best predictor of stunting was gut permeability – an hallmark of environmental enteropathy (...). In summary, we see that stunting is the product of under-nutrition (of both the mother and the child), specific poor feeding practices and micronutrient deficits, a lack of clean water and sanitation, the development of environmental enteropathy and the presence of an abnormal microbiome. Iron deficiency anaemia can be prevented (...) diet with sufficient iron and the other necessary cofactors required for its uptake, iron fortification of staple foods, and the prevention or treatment of diseases such as malaria and hookworm. |

| Author | Year | Publication type | Type of review | Population | Outcome(s) | Setting | Drivers |
|---|---|---|---|---|---|---|---|
| Haile, B. | 2021 | Technical/discussion paper | Narrative review | Children | Stunting; wasting | LMIC, including in the Sahel | (...) immediate determinants (...) such as age and gender. Positive association between being a male child and reduced underweight prevalence. Children who are born small, weighing less than 2,500 grams, are more likely to be undernourished. Exposure to physical illnesses like diarrhoea, anaemia and parasitic infection and fever can also deprive the child of necessary nutrients, resulting in underweight. Emerging research suggests that exposure to toxins, such as aflatoxin and pesticides, may also negatively affect child growth and development (...). SGA and nutritional deficiencies during infancy and childhood, along with other factors such as feeding practices or home environments. Maternal education especially has been identified as a strong predictor of child nutrition using at least one of the indicators of undernutrition – stunting, wasting, and underweight. Maternal education can affect child nutrition in several ways including through better knowledge about the importance of prenatal care and optimal IYCF and better intra-household bargaining power. (...) Adolescent and adult nutritional status (...) The focus on adolescent health and nutrition is vital, as this life stage is often described as the "second window of opportunity" with triple returns from nutritional improvement in the form of better adolescent health now, adult health later, and the health of future generations. Stunting in adolescents is a critical indication of poor nutrition that has built up and is correlated with numerous factors from early life (e.g., insufficient feeding and care practices as infants and children) to the current state, such as poverty and/or illnesses. Child marriage. Child brides are among the most nutritionally vulnerable groups - not only for the girl herself but also for her future children. As adolescent girls are still growing, competition for nutrients is unavoidable between the mother and her foetus, where the mother is at risk of becoming stunted and the foetus in danger of having a low birth weight and facing other postpartum risks including stunting and death. At a social level, child brides are often deprived of their education and decision-making ability, both of which can affect the nutrition of their children. Underlying determinants - household socio-economic status (SES). Economic growth and poverty reduction have been identified as key factors in reducing the burden of hunger and malnutrition (...). Household assets, crop production, and ownership of saving accounts are highly correlated with nutritional outcomes. adults and children living in poorer households have higher likelihoods of suffering from undernutrition, ceteris paribus. Access to social services, including maternal health and antenatal care, also play a vital |

| Author | Year | Publication type | Type of review | Population | Outcome(s) | Setting | Drivers |
|---|---|---|---|---|---|---|---|
| | | | | | | | role in nutritional outcomes. Access to information and infrastructure like roads and electricity tackle undernutrition through their effects on diets and exposure risk of diseases and infections. For example, the likelihood of being stunted is higher among children who live in dwellings that lack electricity. Basic determinants - The environment and various climate-related risks are major determinants of nutrition, especially in economies that rely heavily on rainfed agriculture. These risks can impact nutrition both through their effects on agricultural production and the spread of water- and vector-borne diseases. Warming can induce famine that weakens people and suppresses immune systems and resistance to infection. It can also reduce yields and crop nutrient density while facilitating the spread of pests such as the Tsetse flies that attack livestock. Children who face drought are more likely to be undernourished. (...) rapid urbanisation as one of the contributing factors to malnutrition. role of rural diversification and development of smaller cities (versus mega cities) to bring about a more inclusive economic growth. An urban area may offer better opportunities for improved nutrition, including through better education (of women), WASH, and overall household socioeconomic status. At a basic level, access to public infrastructure, markets and information may be easier in urban areas. On the other hand, a rapidly urbanizing area that faces high unemployment and poverty, inadequate social services, and poor WASH will have poor nutrition. The urban poor who lack cooking and storage facilities inside their residence and who face infrastructural and time constraints may have challenging time acquiring nutritious food. The flourishing of supermarkets in an urbanizing area may provide greater availability and accessibility to diverse foods. At the same time, they may instigate greater access to nutrient-poor, highly processed foods. Lifestyle and environmental changes urban setting may also result s increased environmental pollution or poor WASH due to overcrowding. These developments may inevitably increase the risk of infectious and non-communicable diseases (NCDs). |
| Harper, K. M. | 2018 | Scientific paper | Systematic Review | Children | Stunting | LMIC, including in the Sahel | There was stronger support for the link between (…) intestinal inflammation and stunting. |
| Helldén, D. | 2021 | Scientific paper | (Systematic) Scoping review | Children | Stunting; anaemia | LMIC, including in the Sahel | Potential gains in crop yields from higher average temperatures and carbon dioxide concentrations would be offset by negative effects in the form of heatwaves, lower water availability, changes in the dynamics of crop diseases, and lower nutritional value of crops (for instance lower concentration of iron in foods). Extreme weather events such as flooding have long-term effects on the |

| Author | Year | Publication type | Type of review | Population | Outcome(s) | Setting | Drivers |
|---|---|---|---|---|---|---|---|
| | | | | | | | nutrition status of children, with the most disadvantaged children being at greatest risk. (...) decreases in crop yield and other agricultural variables due to droughts lead to a higher probability of child undernutrition. (...) sub-Saharan Africa could face increased rates of stunting of up to 20% depending on rate of socioeconomic development. (...) Crop diversification has been identified as an adaptation measure in combating child undernutrition. (...) Climate change could force families into poverty through loss of livelihood, additional costs from property damage, and health costs. Particularly relevant: populations already living in poverty or near poverty in rural geographical areas that will be affected most from climate change such as low-elevation coastal zones due to sea level rise, less-favoured agriculture areas, or the Arctic region. (...) The wealth of individuals and families (...) disruptions such as storms in Bangladesh have increased the risk of early child marriage as a way of coping with economic loss. Climate variability, including higher temperatures during prenatal and early childhood years, can lead to significantly less educational attainment, but the relationship between rainfall and level of education differs across regions and rural and urban settings. High ambient air temperature during schooling leads to negative effects on the wellbeing of children whereas females experiencing droughts during childhood have lower educational attainment. In turn, low education has often been cited as one reason for low socioeconomic status that leads to disproportionally higher risk from the effects of climate change. The potential of schools in addressing health impacts from climate change is unknown. losses of sustainable water sources due to sea level rise and flooding could be one of the key drivers of migration. Extreme temperatures, low amounts of precipitation, and elevated levels of air pollution have led to lower birthweight and affected length at birth (...). mental health illness during pregnancy following rapid onset extreme weather events impacted infant behaviour and child height. (...) exposure to particulate pollution during pregnancy and children being small for gestational age, having low birthweight, and later presenting respiratory disorders. (...) A lack of precipitation over time along with many other factors, such as evapotranspiration associated with increased temperatures, can lead to droughts. Droughts have a longer onset and duration than other weather and climate events. |
| Hlimi, T. | 2015 | Scientific paper | Systematic Review | WRA | Anaemia | African countries, | Seasonality; Malaria (seasonal variation indicates that anaemia and malaria are indeed linked and that the two correspond with rainfalls in Sub-Saharan Africa); |

| Author | Year | Publication type | Type of review | Population | Outcome(s) | Setting | Drivers |
|---|---|---|---|---|---|---|---|
| | | | | | | including in the Sahel | primigravidae (first pregnancy); inadequate antenatal care; nutrition deficiencies; intensive agricultural labour during the rainy season |
| Jidong, D. E. | 2021 | Scientific paper | Systematic Review | Children | Stunting | Only countries in the Sahel | Maternal mental health distress. Infants of depressed mothers' significant poorer growth than non-depressed, and more episodes of diarrhoea. |
| Kamal, A. | 2015 | Scientific paper | Narrative review | Children | Stunting; Anaemia | LMIC, including in the Sahel | Exposure to outdoor air pollution and biomass smoke, in particular, is associated with stunted growth (...) and associated with anaemia (...) in children. In children, exposure to PAHs can induce (...) haematological changes, including anaemia. |
| Kassebaum, N. J. | 2016 | Scientific paper | Systematic Review | WRA | Anaemia | LMIC, including in the Sahel | Adults/women (SSA): iron-deficiency anaemia, malaria, hemoglobinopathies, Schistosomiasis. Under 5 years of age: iron-deficiency anaemia, hemoglobinopathies, "other" infectious diseases, and malaria (in endemic areas). |
| Katoch, O. R. | 2022 | Scientific paper | Systematic Review | Children | Stunting; wasting; undernutrition | LMIC, including in the Sahel | Household income/poverty, maternal education, availability of sanitation facilities at home, birth order, birthweight, breastfeeding & caring practices, socioeconomic status, cooking area & fuel used; sex of the child; maternal nutritional status; family size; age of the child |
| Keino, S. | 2014 | Scientific paper | Systematic Review | Children | Stunting | African countries, including in the Sahel | Male sex; maternal nutrition before and during pregnancy; maternal age; Maternal occupation; maternal education; household income; household lower socioeconomic status; household size; maternal employment; urban/rural residence; Living conditions, such as housing and sanitation, |
| Kennedy, E. | 2020 | Scientific paper | Systematic Review | Children | Stunting; wasting | LMIC, including in the Sahel | Safe water access, sanitation and women's education, gender equality and quality of food (not just quantity) were significant drivers in reducing stunting. eliminating gender disparities in income, decision-making, access to financial and other resources improves household food security, diet diversity and/or nutritional status of household members. |
| Lawn, J. E. | 2014 | Scientific paper | Narrative review | Children | Stunting | LMIC, including in the Sahel | Babies born preterm and SGA have the highest risk of stunting in childhood. |
| Lelijveld, N. | 2022 | Technical/ discussion paper | Narrative review | Children | Stunting; wasting | Only countries in the Sahel | Wasting and stunting as drivers of each of these outcomes. In addition: optimising RUF formulations, especially those with adequate essential amino acids to activate biological growth pathways, optimising RUF dosage, increasing the intake of animal-source foods and better post-discharge support may contribute to optimal linear growth in children who survive wasting. |
| Lemoine, A. | 2020 | Scientific paper | Narrative review | Children | Anaemia | African countries, including in the Sahel | Risk factors for childhood anaemia: iron dietary deficiency/inadequate intake; iron content of soils and crops; maternal socioeconomic status; maternal nutritional status; prolonged breastfeeding (breastfeeding duration); |

| Author | Year | Publication type | Type of review | Population | Outcome(s) | Setting | Drivers |
|---|---|---|---|---|---|---|---|
| | | | | | | | geophagia; genetic variations enhancing iron absorption; Malaria; digestive and urinary parasitosis; other digestive diseases. |
| Mackinnon, E. | 2019 | Scientific paper | Narrative review | Children and WRA | Stunting; anaemia | African countries, including in the Sahel | No access to household sanitation was associated with elevated risk of anaemia in adolescent girls and anaemia is also associated with high rates of stunting (…) |
| Maitra, C. | 2018 | Technical/discussion paper | Systematic Review | Children and WRA | Stunting; wasting; anaemia | LMIC, including in the Sahel | direct association between food insecurity and stunting for children in lower-middle and upper-middle income countries, evidence of links between food insecurity and either child wasting is almost absent. In addition, food insecurity increases the risk of (...) anaemia in women. |
| Mardani, R.A.D. | 2022 | Scientific paper | Systematic Review | Children | Stunting; undernutrition | LMIC, including in the Sahel | Providing breastfeeding or exclusive breastfeeding can benefit children under 5 years of age in developing countries reduce overall undernutrition and the stunting type of undernutrition. |
| Margatot, D.I. | 2022 | Scientific paper | Systematic Review | Children | Stunting | LMIC, including in the Sahel | women's empowerment has a significant impact on preventing stunting |
| Marshall, A. I. | 2021 | Scientific paper | (Systematic) Scoping review | Children | Undernutrition | LMIC, including in the Sahel | drivers under scenarios of crisis (economic, political, environmental): high prevalence of child morbidity and mortality; displacement of children had an effect on inadequate dietary intake, due to ration cuts and opting for alternative cereal foods, cheaper; nutrition habits; a review of the impact of drought on child undernutrition found that, though there are higher levels of undernutrition during droughts, the crisis itself is not the cause, but rather, only a trigger for already vulnerable settings; already poor rural areas; increased risk of malnutrition among boys compared to girls, with the most affected age group being children less than 18 months old, while(…) reported a higher percentage of anaemia among girls than boys (25% to 71.5% for girls and 43.6% to 60.9% for boys) following crisis. |
| Maulina, R | 2022 | Scientific paper | Systematic Review | Children | Stunting | LMIC, including in the Sahel | Depression during pregnancy (antenatal depression) |
| Millward, D. J. | 2017 | Scientific paper | Narrative review | Children | Undernutrition | LMIC, including in the Sahel | Maternal drivers/pregnancy: Maternal short stature, Poor diet, Intra-uterine infection, Systemic infection/inflammation; Infancy: Early weaning; Poor diet/environment, Recurrent infections, Poor stimulation/nurturing; childhood: Poor diet (dietary energy, iodine, amino acids and Zn), Poor environment, Recurrent infections; access to nutritional interventions which have improved linear growth, (e.g., provision of milk). |

| Author | Year | Publication type | Type of review | Population | Outcome(s) | Setting | Drivers |
|---|---|---|---|---|---|---|---|
| Obasohan, P.E. | 2020 | Scientific paper | (Systematic) Scoping review | Children | Stunting; wasting; underweight | LMIC, including in the Sahel | The risk factors for malnutrition identified included age, gender, comorbidities. (such as diarrhoea), maternal education, household wealth and place of residence |
| Ode, D. | 2022 | Scientific paper | Systematic Review and Meta-analysis | Children | Stunting | LMIC, including in the Sahel | Toddlers who have a history of being born with low birth weight have a risk of experiencing stunting as much as 2.19 times compared to toddlers who have a history of birth with normal birth weight |
| Odo, D. B. | 2021 | Scientific paper | Systematic Review | Children | Stunting; anaemia | LMIC, including in the Sahel | Household air pollution. Three of these studies reported moderate to severe stunting and anaemia relative risk ratios among children living in households where cooking was done with only biomass (wood, crop waste, or dung) (…). All birthweight-related studies took households that were using electricity, LPG, or natural gas as a reference (i.e., unexposed to polluting fuels) group. Three out of five studies reported adverse associations, while the remaining two reported no effect. |
| Owais, A. | 2021 | Scientific paper | Systematic Review | WRA | Anaemia | LMIC, including in the Sahel | PROXIMAL CAUSES: Maternal characteristics (age, BMI, health history and status - excessive bleeding, infection burden, early onset of childbearing, high parity/short birth spacing, pregnancy and lactation status); Dietary intake (access to diverse food sources, access to enough food, access to fortified food); Health services utilisation (access to antenatal care, access to emergency obstetric and newborn care, access to family planning/contraceptives, access to micronutrient supplementation, nutrition counselling, access to malaria prophylaxis, access to deworming); INTERMEDIATE CAUSES: socioeconomic factors (education/occupation, household wealth, urban/rural residence); Healthy household environment (access to clean water and sanitation); DISTAL CAUSES: Ecological factors (political economy, climate/environment, health policies and systems, cultural norms and behaviour, gender equity/empowerment) |
| Pennington, A. | 2018 | Scientific paper | Systematic Review | Children and WRA | Undernutrition; anaemia | LMIC, including in the Sahel | Women's low control of their living environments as a driver of: Malnutrition (for infants, children and women), infant and child growth, gender disadvantage in childhood nutritional status/malnutrition (for girls), low birth weight and anaemia (for women) |
| Pratley, P. | 2016 | Scientific paper | (Systematic) Scoping review | Children | Stunting; wasting; underweight; anaemia | LMIC, including in the Sahel | Women empowerment |

| Author | Year | Publication type | Type of review | Population | Outcome(s) | Setting | Drivers |
|---|---|---|---|---|---|---|---|
| Prendergast, A. J. | 2016 | Scientific paper | Narrative review | Children | Malnutrition/ undernutrition | LMIC, including in the Sahel | Diarrhoea slows ponderal and linear growth, more in boys than girls. Although the reasons for reduced growth are multifactorial, a recent Zimbabwean study showed that diarrhoea can directly reduce circulating levels of insulin-like growth factor-1. A condition called environmental enteric dysfunction (EED), which is almost universal in impoverished settings, is also associated with stunting. |
| Rachmayanti, RD | 2022 | Scientific paper | Systematic Review | Children | Stunting | LMIC, including in the Sahel | Exclusive breastfeeding may reduce the risk of stunting as infants and children under five highly need nutrition in breastmilk. Factors that affect exclusive breastfeeding include knowledge of mothers and families about exclusive breastfeeding, early initiation of breastfeeding, complementary feeding, and non-health factors. |
| Reinhardt, K. | 2014 | Scientific paper | Narrative review | Children | Stunting | LMIC, including in the Sahel | National economic indicators; the increases in wealth at a country level need to be equitable and investments in health and nutrition; household wealth; lack of basic infrastructure (water, sanitation, electricity, and shelter); improved community resources (health centres); Cultural factors: women's autonomy and fertility practices; in SSA, higher birth order (i.e., having more older siblings) was associated with an increasing risk of stunting; gender. Shocks: droughts, floods, civil conflicts; Food security (maternal knowledge of care and feeding practices, maternal chores or livelihoods, and family eating behaviours (e.g., who eats first; the size of ind. rations); Decreased dietary diversity and lower household income. Seasonality (if directly affects the disease environment). Inadequate care practices (lack of exclusive breastfeeding and poor IYCF practices). Family housing quality was negatively associated with stunting (type of dwelling, availability of a safe water supply, adequacy of sanitation, and rubbish collection. Poor household environmental conditions were associated with (...) increased risk of stunting. Positive correlation between water and sanitation hygiene(WASH) and stunting. Association between greater diet diversity and reduction in or lack of stunting. The risk of a child being stunted at 2 years of age increases with the incidence of diarrhoea; poor intestinal absorption; environmental enteropathy; open defecation. Maternal stature and BMI and mother's age at childbirth. |
| Rosinger, A. Y. | 2020 | Scientific paper | Narrative review | Children | Stunting; undernutrition | LMIC, including in the Sahel | Water insecurity (availability, accessibility, use, and reliability) as a driver of malnutrition and poor growth during infancy; and stunting during childhood to adolescence |

| Author | Year | Publication type | Type of review | Population | Outcome(s) | Setting | Drivers |
|---|---|---|---|---|---|---|---|
| Salm, L. | 2021 | Scientific paper | (Systematic) Mapping review | Children and WRA | Stunting; wasting; anaemia | African countries, including in the Sahel | Immediate - dietary practices, health status; Underlying - Food security, care practices, living environment, gender; Basic - economical/social context, enabling environment, environmental context |
| Sassi, M. | 2022 | Scientific paper | Systematic Review | Children | Undernutrition | LMIC, including in the Sahel | Significant and negative association between conflict and child malnutrition. (…) Longer-term conflict had a greater effect on child malnutrition, measured as wasting and stunting, than the shorter-term events. (…) political violence was positively associated with both wasting and stunting. interaction between conflict and drought. (...) a strong association between exposure to armed conflict (severity/typology) and the risk of severe and moderate childhood underweight. |
| Schelling, E. | 2016 | Scientific paper | Narrative review | Children | Undernutrition | LMIC, including in the Sahel | Pastoralism livelihood (In rural Chad, proportions of acute malnutrition were not higher in pastoral children compared to sedentary children. But both populations showed acute malnutrition proportions above 10% at the end of the dry season. In contrast, pastoralist women were significantly more under-nourished (up to 48% in the dry season) than settled women (...). Acute malnutrition in children was significantly associated with anaemia and selected intestinal parasites. Other authors have observed that pastoralist mothers deprive themselves when food is in short supply(...) children of three settled communities, one in a town that relies on relief agencies for food supply, showed three times the level of stunting and wasting when compared to the surrounding nomadic and semi-mobile pastoralists. These differences were attributed to reduced access to milk and higher reliance on cereals in the settled communities. During the wet season, when milk was abundant and grain prices were highest, milk provided almost 90% of dietary energy to Turkana pastoralists and 80% to the Maasai.) |
| Sheehan, M. C. | 2022 | Scientific paper | Narrative review | Children and WRA | Stunting; wasting; anaemia | LMIC, including in the Sahel | (…) a review of drought impacts in Africa found increased anaemia, (…) and child nutrition-related disabilities, including stunting and wasting. (…) In a systematic review, during droughts in India (…) malnutrition and anaemia. Droughts in Madagascar, East Africa, and Lake Chad add millions to those exposed to risk of malnutrition and anaemia (...) |

| Author | Year | Publication type | Type of review | Population | Outcome(s) | Setting | Drivers |
|---|---|---|---|---|---|---|---|
| Simwanza, NR | 2022 | Scientific paper | (Systematic) Scoping review | Children | Stunting; wasting; underweight | African countries, including in the Sahel | Stunting: Short birth interval. Birth intervals of less than 18 months is a risk factor for stunting; the prevalence of stunting was greater among boys than girls, and the prevalence was higher in children born outside the hospital; children born as first or second in order were more likely to be stunted compared with those born third in line or later. Demographic factors. Geographic location is one of the factors of child malnutrition. Children living in rural areas were found to be more stunted than their counterpart in urban areas. The gap observed on stunting prevalence between children from uneducated mothers or those whose mothers have a primary school level of education compared with those from mothers with secondary or high level of education remains high. The mother's characteristics such as short birth interval (less 18 months) influenced elevated risk of stunting and wasting. Preceding birth interval is the other important variable which is associated with nutritional status of children. There is an inverse relationship between the length of the preceding birth interval and the proportion of children who are malnourished (Endris et al., 2017). Age of child. Age of child is a significant factor of child malnutrition. Younger children are less likely to suffer from malnutrition than older ones because they are breastfed. This was likely to be so because the problem of lack of food in the home did not directly affect them. Additionally, older children also face the risk of eating contaminated food is reduced. In the contrarily, (…) found that children who were still breastfeeding had a higher risk of being underweight than those who had been weaned. In rural Ethiopia, children aged 12–23 months were more prone to malnutrition than those who were below six months of age. babies born underweight are three times more likely to be stunted than children of the same age group with normal or higher birth weight. |
| Smith, L. E. | 2017 | Scientific paper | Systematic Review | WRA | Anaemia | LMIC, including in the Sahel | (…) negative association between an aflatoxin biomeasure and birthweight. (…) Aflatoxin exposure has been associated with anaemia (Ghanaian women). |
| Tadesse, SE | 2022 | Scientific paper | Systematic Review | Children | Anaemia | African countries, including in the Sahel | Sex of a child, maternal educational status, residence (urban/rural), and family size were the pooled determinants of anaemia among under-five children in Africa. |
| Thurstans, S. | 2020 | Scientific paper | Systematic Review and Meta-analysis | Children | Stunting; wasting; underweight | LMIC, including in the Sahel | Our review indicates that undernutrition in children under five is more likely to affect boys than girls though the magnitude of these differences varies and is more pronounced in some contexts than others. |

| Author | Year | Publication type | Type of review | Population | Outcome(s) | Setting | Drivers |
|---|---|---|---|---|---|---|---|
| Thurstans, S. | 2022 | Scientific paper | Systematic Review | Children | Stunting; wasting | LMIC, including in the Sahel | Episodes of wasting contribute to stunting and, to a lesser extent, stunting leads to wasting. Risk factors (for both): poor maternal nutrition, high parity, low education levels, low birth weight (LBW) and/or length and poor feeding practices, poor socioeconomic conditions, seasonality, |
| UNICEF | 2014 | Technical report/ publication | Narrative review | Children | Undernutrition | LMIC, including in the Sahel | Climate change is altering weather patterns in ways that can affect the geographic range, seasonality and incidence of health outcomes (…undernutrition). Rising temperatures that facilitate the replication of some pathogens, and more flooding events that damage water treatment facilities and/or spread pathogens, could increase the burden of disease. Combined with an increase in the price of food and basic resources, many affected households could not afford basic supplies or food, thus increasing the rate of undernutrition, particularly among pregnant women and children under five. Expected increases in the world population to 9.6 billion by the middle of the twenty-first century12 and climate change are projected to increase the numbers at risk of hunger and undernutrition, particularly in Africa |
| Vaivada, T. | 2020 | Scientific paper | Systematic Review | Children | Stunting | LMIC, including in the Sahel | Asset index/ household income, maternal education, paternal education, open defecation, sanitation infrastructure, Improved access to safe water source, mother attending 4 antenatal care visits with 1 visit with a skilled medical professional has been associated with a reduced risk of stunting, improved access to health care and skilled birth attendance at a health facility, proportion of households with bed nets, vaccination coverage, being breastfed at birth, ever breastfeeding, breastfeeding duration, longer time interval between births has been associated with lowered odds of stunting, family planning, declines in parity, fertility rate (births per 1000 women), maternal height, maternal age, low birthweight, inadequate dietary diversity, diarrhoea incidence, |
| Vilcins, D. | 2018 | Scientific paper | Systematic Review | Children | Stunting | LMIC, including in the Sahel | Sanitation: access to (improved) sanitation - yes/no personal latrine ownership// or % of latrines available in the household or neighbourhood; % open defectors; access to WASH program; Hygiene: hand washing, presence of soap and water near latrine; hygienic environmental settings are protective against child stunting, lack of adequate waste disposal in the community; Housing: dirty floors in the home; Others: environmental enteropathy; geophagia; exposure to intestinal parasites, exposure to foodborne mycotoxins; poor quality cooking fuels. |

| Author | Year | Publication type | Type of review | Population | Outcome(s) | Setting | Drivers |
|---|---|---|---|---|---|---|---|
| WCA Regional Nutrition Working Group | 2022 | Technical report/ publication | Narrative review | Children | Malnutrition/ undernutrition | Only countries in the Sahel | widespread household food in security, inadequate dietary and care practices for infants and young children, high incidence of child hood illnesses, widespread poverty, inadequate access to water and sanitation and health services, as well as gender and other social norms. inadequate infant and young child feeding practices persist. Among the G5 Sahel countries, the lowest proportion of children having a minimum acceptable diet is found in Mali (9.8%), followed by Chad (11.5%), Niger (19.5%), Mauritania (21.7%) and Burkina Faso (23.9%). Food Security situation. Insecurity (...); massive populations displacement (...); armed attacks on communities, schools, health centres and other public institutions and infrastructure have disrupted livelihoods and access to social services including education and health care. |
| Wirth, JP | 2016 | Scientific paper | Narrative review | Children | Stunting; undernutrition | Only countries in the Sahel | birth size, recent illness (e.g., diarrhoea, respiratory infection) and maternal height and education. A higher prevalence of stunting has been detected when children started complementary feeding after 6months or 12months of age. children with a high meal frequency (i.e., three meals per day) were less likely to be stunted than their peers. Household characteristics that are often associated with child growth: low household socioeconomic status, dwelling quality, exposure to indoor smoke because of low quality cooking fuel, number of children <5 years, dependency ratio, family size and female sex of the household head. |
| Wrottesley, S. | 2016 | Scientific paper | Systematic Review | WRA | Anaemia | LMIC, including in the Sahel | LBW greater in infants born in farming than in pastoral communities; maternal height <156 cm; maternal underweight during pre-pregnancy and pregnancy; maternal anaemia; Lower LBW among infants whose mothers had protein-energy supplementation (pregnancy) and multiple micronutrient supplementation (pregnancy); daily iron supplementation (pregnancy). Anaemia: higher among pregnant women from pastoral communities (vs. farming communities); higher in rural women, |

# Annex 3. Drivers of undernutrition in the Sahel and in LMIC globally

***Table S3.*** *Drivers of undernutrition identified in the review, by dimensions and categories, which been described in countries in the Sahel and globally (n=72 publications). (n=72)*

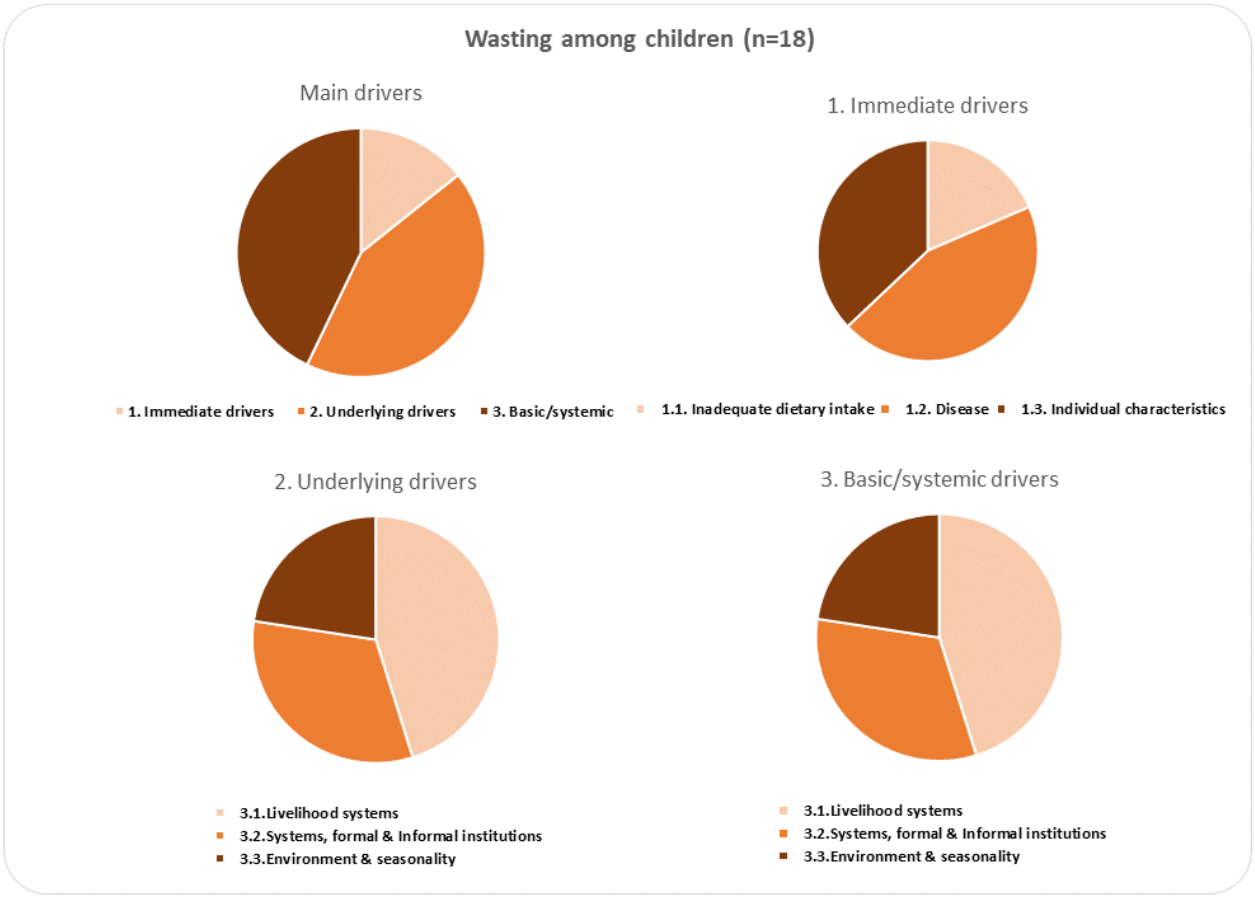
| Dimensions / Categories | Drivers of Undernutrition | Contextualisation | |
|---|---|---|---|
| | | Sahel | LMIC Globally |
| **1.IMMEDIATE:** | | | |
| **1.1.Inadequate dietary intake** | | | |
| **1.1.1.Child** | | | |
| | Poor diet quality/ unhealthy diet/ Inadequate dietary intake [22–29] | ✓ | ✓ |
| | Low dietary diversity / Minimum Acceptable Diet [17,23,25–30] | ✓ | ✓ |
| | Minimum acceptable diet [21,25,26] | ✓ | ✓ |
| | Low meal frequency (≤3x/day)/ Minimum Meal Frequency (MMF) [32][31] | ✓ | ✓ |
| | Low energy intake [28,33]/ Low dietary energy supply per capita [29] | | ✓ |
| | Low protein intake [25,33] | | ✓ |
| | Low micronutrient intake: iodine [25,33], Zn [25,33], Vitamin A [32], Iron [27] | | ✓ |
| | Diet quantity [23] | | ✓ |
| | Geophagia [33] | | ✓ |
| | Diet quality of food aid: low in protein [23] and vitamins [23], small rations [24], low acceptability [24] | | ✓ |
| | Food digestibility [23] | | ✓ |
| **1.1.2.Maternal** | | | |
| | Poor diet quality (during pregnancy)[25,33–35] | ✓ | ✓ |
| **1.2.Disease** | | | |
| **1.2.1.Child** | | | |
| | Mortality [23] | ✓ | ✓ |
| | Communicable diseases [23,28,36–40]/ Water- and vector-borne diseases [41] | ✓ | ✓ |
| | Infection [41–44] / Recurrent infections [25]/ Parasitic infection (e.g., digestive and urinary parasitosis; intestinal parasites) [33][45] | ✓ | ✓ |
| | Malaria [21,28,31,32,41,42][27] / High malaria prevalence [34] | ✓ | ✓ |
| | Poor gut health/ Enteric Pathogen Infections /Environmental Enteric Dysfunction [22,27,44,46–48]/ Disrupted gut microbiota [27,49]/ Intestinal inflammation [50]/ Gut permeability [27]/ Other digestive diseases [33] | ✓ | ✓ |
| | Recent illness (e.g., fever in last 2 weeks, acute respiratory infection - ARI, high prevalence of ARI, Diarrhoea, high diarrhoea prevalence) [21,24–27,29,32–34,36,40,43,45,48,49] | ✓ | ✓ |
| | Undernutrition (e.g., nutritional status, stunting, wasting, anaemia, underweight) [22,28,32,36,40,48,51–53] | ✓ | ✓ |
| | Disease/disability/morbidity [22,60]/ High incidence of childhood illnesses [30] | | ✓ |
| | Non-communicable diseases [41] | | ✓ |
| | Food allergy [23] | | ✓ |
| | Nutrition/mineral/vitamin deficiencies [54] - iron [32,73], Vitamin A [32] | | ✓ |
| | Malabsorption malnutrition [42] | | ✓ |
| | Suppressed immune system [41] | | ✓ |
| | Genetic variations enhancing iron absorption [33] | | ✓ |
| | Low levels of physical activity [22] | | ✓ |
| **1.2.2.Maternal** | | | |
| | Infection during pregnancy - systemic [25], intra-uterine [25], malaria [54]/ Infection burden [55] | ✓ | ✓ |
| | Mental illness during pregnancy [56]/ Antenatal depression [57] | ✓ | ✓ |
| | Nutritional status: low BMI [28,32–34,48,54,55,58]; high BMI [27]/ Nutrition [52,59] (during pregnancy [27]) /MUAC <23 cm [35] | ✓ | ✓ |
| | Micronutrient deficiencies (pregnancy) [33] | ✓ | ✓ |
| | Adolescent health and nutrition [41] | | ✓ |
| | Maternal stress [42,94] | | ✓ |

| Dimensions / Categories | Drivers of Undernutrition | Contextualisation | |
|---|---|---|---|
| | | Sahel | LMIC Globally |
| | **1.2.3.Household/community/national** | | |
| | Stress and psychological trauma - household level [23] | | ✓ |
| | Household HIV status [32] | | ✓ |
| | Community HIV prevalence [32] | | ✓ |
| | Disease burden (national) [83] | | ✓ |
| **1.3.Biological/Individual characteristics** | | | |
| **1.3.1.Child** | | | |
| | Sex (male) [23,24,28–30,32–34,41,46,48,58–63] | ✓ | ✓ |
| | Age [23,24,28,29,32,34,41,58,60–63] | ✓ | ✓ |
| | Birth order (i.e., having more siblings) [29,32,34,48,61] | ✓ | ✓ |
| | Type of birth (multiple) [28,29,32,34,54,64] | ✓ | ✓ |
| | Low birthweight [28,32,34,41,52,54,61,65] | ✓ | ✓ |
| | Small for gestational age (SGA) [28,41,52,66]/ Birth size [31,32]/ Perceived child's birth size [32] | ✓ | ✓ |
| | Preterm birth [28,66] | | ✓ |
| **1.3.2.Maternal/caregiver** | | | |
| | Age [28,29,32,34,54,55,58] | ✓ | ✓ |
| | Low parity/short interpregnancy intervals [29,32,34,35,52,54,55,59,61,67] | ✓ | ✓ |
| | Height (short) [25,27,29,31,32,34,43,48,68] | ✓ | ✓ |
| | First pregnancy (primigravidae) [67] | | ✓ |
| | Pregnancy status [55] / breastfeeding status [32] | | ✓ |
| **2.UNDERLYING:** | | | |
| **2.1.Insufficient household food security** | | | |
| | Food insecurity (household, child's) [23,29,30,37,54,59,60,69–73]/ High levels of acute food insecurity [26] | ✓ | ✓ |
| | Household agricultural/livestock production [22,32,34,59,74] | ✓ | ✓ |
| | Food access/availability [22,37] | | ✓ |
| | Food utilisation [22,37] | | ✓ |
| | High Food price / low affordability [22,23,26,90] | | ✓ |
| | Cooking & storage facilities [41]/ cooking area [34]/ Ease of food preparation and storage [23] | | ✓ |
| | Food safety [22,23] | | ✓ |
| **2.2.Inadequate social & care environment** | | | |
| **2.2.1.Inadequate care environment** | | | |
| | Poor breastfeeding practices (*e.g.,* no breastfeeding; non-exclusive until 6 months; duration)[22,23,26–28,32–34,41,48,54,64,75] | ✓ | ✓ |
| | Poor or inadequate complementary feeding practices (e.g., early weaning; starting complementary feeding after 6 or 12months) [22,25,28,31,34,48,49,54,74,75] | ✓ | ✓ |
| | Family care structure/ child displacement from the family/unaccompanied/ orphaned [23,24,26]/ child abandonment [76]/paternal orphan [32] | ✓ | ✓ |
| | Stress of displacement [42] | ✓ | ✓ |
| | Poor feeding practices (e.g., non-adherence towards WHO optimal feeding recommendations) [26,30,52,60,70] | | ✓ |
| | Use of formula/ infant-feeding products [22,23] | | ✓ |
| | Nutrition awareness/education: poor maternal awareness of child's nutritional status/ knowledge on care and feeding practices, maternal chores or livelihoods, and family eating behaviours (e.g., who eats first; the size of ind. rations) [28,48,75,89] | | ✓ |
| | Poor stimulation/nurturing during infancy [25] | | ✓ |
| | **2.2.2.Insufficient social services** | | |
| | Access to social protection system/ social services [26,74] | | ✓ |
| | Limited / interrupted social safety nets [70] | | ✓ |
| | Interrupted / discontinued education for children and adults [30,70] | | ✓ |
| **2.3.Insufficient health services & unhealthy environment** | | | |
| **2.3.1.Insufficient health services** | | | |
| | Access to health centres/community resources/health facilities [29,48] | ✓ | ✓ |

| Dimensions / Categories | Drivers of Undernutrition | Contextualisation | |
|---|---|---|---|
| | | Sahel | LMIC Globally |
| | Access to antenatal/prenatal care/ Antenatal visits/Antenatal care 4+ visits [22,29,34,35,54,55,59,60,67,70,74] | ✓ | ✓ |
| | Access to/quality of maternal care [59,74] | ✓ | ✓ |
| | Access to family planning/reproductive health [59,60,70] / contraceptive use [28,54,55,59] | ✓ | ✓ |
| | Access to deworming in the last 6 months/Deworming status [32,60] | ✓ | ✓ |
| | Immunisation (status) [22,28,60]/ (Ever had) vaccination [32] | ✓ | ✓ |
| | Health-seeking behaviours [22]/ Reduced care seeking [70]/ mother health-seeking [32] | ✓ | ✓ |
| | Maternal supplementation (pregnancy) [35] | ✓ | |
| | Has health insurance/ Maternal health insurance [32] | ✓ | ✓ |
| | Place of birth delivery [32,54,61]/ Access to professional or skilled birth [29,54,55] | ✓ | ✓ |
| | Healthcare services/ systems availability [22,23,26,30,39,59,70] | | ✓ |
| | Healthcare quality/ Limited service and supplies for regular maternal and childcare delivery (e.g., immunisation) [70] | | ✓ |
| | Early detection and treatment of wasting [26] | | ✓ |
| | Access to new-born care [59] | | ✓ |
| | Access to support for breastfeeding, feeding and care practices for young children [26] | | ✓ |
| | Access to malaria prophylaxis [55] | | ✓ |
| | Access to deworming in the last 6 months/Deworming status [32,60] | | ✓ |
| | Health costs [54,56] | | ✓ |
| **2.3.2.Unhealthy environment** | | | |
| | Poor WASH conditions (e.g., hand washing, presence of soap and water near latrine; hygienic environmental settings; lack of adequate waste disposal in the community, household hygienic conditions; dirty floors) [22,23,26,41,46–48,59,60] | ✓ | ✓ |
| | Poor access to (safe) sanitation [26–28,30,32,34,47,51,54,55,69,70] | ✓ | ✓ |
| | Water insecurity (low availability, accessibility, use, reliability) [77] / Low or poor access to clean water [26–28,30,32,34,38,39,45,55,69,70] | ✓ | ✓ |
| | Open defecation [34,47,48,54,59] | ✓ | ✓ |
| | Dwelling quality [31,34]/ Family housing quality (type of dwelling, availability of a safe water supply, adequacy of sanitation, and rubbish collection) [48]/ Lack of basic infrastructure (water, sanitation) [48,58] | ✓ | ✓ |
| | Exposure to indoor smoke because of low quality cooking fuel [31]/ Poor quality cooking fuels [32,47]/ Household air pollution (from solid fuel use)/ Type of household fuel use for cooking [34,78] | ✓ | ✓ |
| | Exposure to outdoor air pollution/biomass smoke/ PAHs [56,74,79] | ✓ | ✓ |
| | Exposure to foodborne mycotoxins [47]/ aflatoxins [74,80,81]/ intestinal parasites [47] | ✓ | ✓ |
| | Access/ type of [29]toilet facilities [32]/ Personal latrine ownership [47]/ Proportion of latrines available in the household or neighbourhood [47] | | ✓ |
| | Exposure to lead (e.g., through artisanal gold mining) [95] | | ✓ |
| | Exposure to pesticides [25] | | ✓ |
| **3.BASIC/SYSTEMIC:** | | | |
| **3.1.Livelihood systems** | | | |
| **3.1.1.Livelihood resources, strategies & goals** | | | |
| | Household /maternal wealth/wealth index/ increased poverty [27,29,32,34,55,56,74] | ✓ | ✓ |
| | Ownership of radio [32]/ Ownership of tv [32]/ land owned [32]/ Use of internet facility [32] | ✓ | ✓ |
| | Low household education [22,52,55]/maternal education [28,29,31,32,34,35,41,54,58–62]/ paternal education [29,54]/ Parental literacy rate [54] | ✓ | ✓ |
| | Occupation [54,55] (maternal [32,58]; paternal[32])/ Unemployment [34,41] | ✓ | ✓ |
| | Family size [29,31,34,35,58,60,62]/ Number of children <5 years old in the household [31,32]/ number of dependent children [32]/ dependency ratio [31]/ Household crowding [54] | ✓ | ✓ |
| | Loss of family providers [42] | ✓ | ✓ |
| | Sex of household head [31,32]/ Single parenting [32]/ Maternal marital status [32] | ✓ | ✓ |
| | Human capital [82] | ✓ | |
| | Region/province/place of residence /urban-rural residence [24,28,29,32,35,54–56,58–62,68] | ✓ | ✓ |

| Dimensions / Categories | Drivers of Undernutrition | Contextualisation | |
|---|---|---|---|
| | | Sahel | LMIC Globally |
| | Low household socioeconomic status [22,27–29,31,33,34,41,52,55,58,59] | | ✓ |
| | Low Income/Reduced income and limited financial resources [26,38,48,54,58,69,70] | | ✓ |
| | Reduced purchasing/spending power [26,70]/ Household food share of total expenditure [32] | | ✓ |
| | Living in evacuation shelters or temporary housing [22,23,48,58]/ Displaced families residing in camps [26] | | ✓ |
| | Household materials quality [29]/ Housing or household conditions [32,59] | | ✓ |
| | Access to electricity [41,48,58] | | ✓ |
| | Household assets [41]/ Ownership of saving accounts [41] | | ✓ |
| | Farming community (vs. Pastoralist)/ Pastoralism [34,68,96] | | ✓ |
| | Slum residence [28] | | ✓ |
| | Access to roads [41] | | ✓ |
| | Ethnic groups [23] | | ✓ |
| | Religious groups [23] | | ✓ |
| | Indigenous [29] | | ✓ |
| | Property damage [56] | | ✓ |
| | Changes to livelihoods [82] | | ✓ |
| **3.2.Systems, formal & Informal institutions** | | | |
| **3.2.1.Governance & Political Economy** | | | |
| | Political economy [24,54,55] | ✓ | ✓ |
| | Poverty [22,23,30,41,83] | ✓ | ✓ |
| | Poor education [83]/ Low illiteracy rate [32,59]/ Female education [29,69] | ✓ | ✓ |
| | Migration [56]/ Mountainous population migration [54]/ Massive population displacements [26,30] | ✓ | ✓ |
| | Urbanisation [22,40,41] | ✓ | ✓ |
| | Civil Insecurity [23,26,39]/ Violence [82] | ✓ | ✓ |
| | Emergency preparedness [23] | ✓ | ✓ |
| | Human-induced disasters[23]: Conflicts/Armed conflicts/civil or communal conflicts/protracted armed conflicts [23,26,30,42,48,82,84,85]/ place of birth near or born during a conflict [29,47] / exposure to conflict (days or months and/or severity/typology) [29,85] | ✓ | ✓ |
| | Other disasters - Epidemics or Pandemics: Mortality epidemics [82]/ Measles epidemic [39]/ Coronavirus Disease 2019 (COVID-19) pandemic [26,70] | ✓ | ✓ |
| | Country/regional development [23,41,48,56,59] | | ✓ |
| | Gross Domestic Product per capita [29,32] | | ✓ |
| | Price shocks/inflation [23,82]/ Price volatility associated with seasonality [82] | | ✓ |
| | Equitable economic growth [48]/ Out of pocket spendings [59] | | ✓ |
| | Investments in health and nutrition [48]/ Health spending [59]/ Deprioritised context and compromised enablers (e.g., policy diversion to urgent care, reduced social sector spending or diversion to COVID response, increased inequity) [70] | | ✓ |
| | Enabling environment: Capacity building [22]/ Domestic resources mobilisation [22] | | ✓ |
| | Employment rate [54] | | ✓ |
| | Sociodemographics [22]/ Female to male life expectancy [29]/ Population density/overcrowding [41] | | ✓ |
| | Political instability [82]/ Politics [22] | | ✓ |
| **3.2.2.Food & Health systems** | | | |
| **3.2.2.1.Food Systems** | | | |
| | Household access to irrigation [38]/ Low water availability [56] | ✓ | ✓ |
| | Disruptions/limited/interrupted food supply chains [23,26,70] | ✓ | ✓ |
| | Foreign economic embargos / "Food as a weapon of war" [42] | ✓ | ✓ |
| | Agriculture [23]/ Type of agriculture (rainfed vs…?) [41] | | ✓ |
| | Low crop production/crop yields/food harvest [23,26,37,56,59,82] | | ✓ |
| | Crop nutrient density [22]/ Nutritional value of crops (e.g., Iron content of soils and crops) [33,56] | | ✓ |

| Dimensions / Categories | Drivers of Undernutrition | Contextualisation | |
|---|---|---|---|
| | | Sahel | LMIC Globally |
| | Crop diseases (changes in the dynamics) [56] | | ✓ |
| | Destruction of agriculture and persistent insecurity [42] | | ✓ |
| | Low livestock production [23,82] | | ✓ |
| | Food shortage/ food scarcity/ limited food stocks/ food environment disruptions [22,26] | | ✓ |
| | Access to public infrastructure (e.g., food stores [23], supermarkets [41]) | | ✓ |
| **3.2.2.2.Health Systems** | | | |
| | National Nutrition policy [22,24,54] | ✓ | ✓ |
| | Low health system quality [23,28,70]/ Health system degradation [23]/ Low surge capacity [23] | ✓ | ✓ |
| | Health worker availability [59] | | ✓ |
| | Nutrition programming [22] | | ✓ |
| | Maternal, new-born and child health programs/care [54,59] | | ✓ |
| | Health policies and systems [55] | | ✓ |
| **3.2.3.Gender, cultural & social norms** | | | |
| | Gender equity/empowerment [55,69]/ Women's autonomy [48,86]/ empowerment [59,83,87,88]/ Family empowerment: Mothers' decision making in the household, education, and environment [89]/ Women's control of their living environment / decision-making ability [41,86] | ✓ | ✓ |
| | Cultural norms and behaviour [55]/ Health & food beliefs/misconceptions/cultural practices [22,23]/ Food cultural acceptability/taboos [23,26] | ✓ | ✓ |
| | Religion [23,32] | ✓ | ✓ |
| | (In)equality [22] | | ✓ |
| | Empowerment [22] | | ✓ |
| | Fertility practices [48] | | ✓ |
| | Child marriage [41,56] | | ✓ |
| | Language spoken [32] | | ✓ |
| | Cultural acceptance [23]/ Individual tolerance [23] | | ✓ |
| **3.3.Environment & seasonality** | | | |
| **3.3.1Climate Variability & Extremes** | | | |
| | Natural disasters [23,24,70]: Flooding [37,48,56,82,90]; Droughts [26,29,37,48,56,82,91]; Storms [56]; Heatwaves/extreme temperatures/ higher temperatures [29,56,90]; aridity [82]; rainfall levels variability [37,56,82]/ excessive rainfall [29,37]/ low amounts of precipitation [56]/ lack of precipitation over time [56]; Pests [41,82] | ✓ | ✓ |
| | Climate vulnerability/change/warming/weather extremes [22,26,41] | | ✓ |
| | Sea level rise, low-elevation coastal zones and losses of sustainable water sources [56] | | ✓ |
| | Less-favoured agriculture areas [56] | | ✓ |
| | Altitude [29] | | ✓ |
| | Evapotranspiration [56] | | ✓ |
| | Loss of forest cover [32] | | ✓ |
| | High levels of air pollution [56]/ Higher carbon dioxide concentrations [56] | | ✓ |
| **3.3.2.Seasonality** | | | |
| | Seasonality [22,30,48,52,67,80,90]/ Wet season [38]/ Growing season [82] | ✓ | ✓ |


Wasting among children (n=18)
Main drivers
1. Immediate drivers
1. Immediate drivers
2. Underlying drivers
3. Basic/systemic
1.1. Inadequate dietary intake
1.2. Disease
1.3. Individual characteristics
2. Underlying drivers
3. Basic/systemic drivers
3.1.Livelihood systems
3.2.Systems, formal & Informal institutions
3.3.Environment & seasonality
3.1.Livelihood systems
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