The impact of **drought** on **malnutrition** among children under five in Ethiopia: a systematic literature review

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Abstract

In Ethiopia, malnutrition among children under five is urgent topic and the increased severity and frequency of droughts can further exacerbate this issue. A number of studies have explored the impact of drought on child malnutrition. Yet, a full understanding is lacking, specifically about, 1.) the impact of drought and compound effects on malnutrition 2.) socio-economic vulnerability factors and 3.) effective interventions. Building on existing knowledge, this systematic literature review aims to further clarify this. Main inclusion criteria were: English peer-reviewed primary or secondary literature and a specific link between drought and malnutrition. Literature was categorized according to similar metrics and topics. 17 (heterogeneous) studies were eligible for inclusion. Results should be interpreted with caution as 10/17 studies had high risk of bias. Nonetheless, this study contributed by providing a coherent overview of existing evidence specifically regarding under five in Ethiopia and the effectiveness of interventions specifically measured during drought. Studies showed a variable drought-related impact on malnutrition, highly depended on chronic social-economic hazards and personal vulnerability. Main vulnerability factors identified were pastoralism, poverty, low maternal education, rural areas, production of numerous crops and poor road connectivity. Six Interventions were identified ranging from food and financial aid to agricultural interventions. The latter was effective only. Policy recommendations are to holistically approach this problem, to involve vulnerable groups by increasing food accessibility and quality, and to diminish underlying chronic hazards. Future research should focus on high quality homogeneous studies and the role of understudied (ecological) compound hazards and interventions.

Keywords: drought - child malnutrition - Ethiopia - vulnerability - hazards - interventions

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List of abbreviations

BMI	Body mass index
DHS	Demographic health survey
ENSO	El Niño–southern oscillation
FAO	Food and agriculture organization of the United Nations
GFP	General feeding program
HAZ	Height-for-age Z-score
JJAS	June-July-August-September
MUAC	Middle-upper arm circumference
NDVI	Normalized difference vegetation index
PRISMA	The preferred reporting Items for systematic reviews and meta-analyses
ROB	Risk of bias
CRP	Comprehensive resilience programming
SSA	Sub-Saharan Africa
U5CM	Under-five child mortality
WASH	Water, sanitation and hygiene
WAZ	Weight-for-age Z-score
WDDS	Women's dietary diversity score
WHZ	Weight-for-height Z-score

1. Introduction

1.1. Problem statement and societal relevance

Climate change contributes to global trends such as increased occurrences of water-related disasters, which can be floods or droughts (Lee et al., 2020). Of those water-related disasters, droughts appear to have the most impactful negative consequences on socio-economic and ecological level, as shown throughout the 20th century (Mishra & Singh, 2010). Between 1990 and 2012, 52 million people worldwide were affected by droughts yearly (Belesova et al., 2019). Negative health consequences of drought are mostly experienced by African and Asian populations due to high population densities, intrinsic vulnerabilities to disease and lower health care facilities in these regions (Belesova et al., 2019; Lee et al., 2020). And it is not without reason that the Food and Agriculture Organization of the United Nations (FAO) underlines that drought is foremost in impacting human health (Lee et al., 2020; Salvador et al., 2020).

Malnutrition is one of the most prominent health-associated consequences of drought (Belesova et al., 2019; Lieber et al., 2022). According to the WHO, malnutrition is defined as having excess, deficiency or an imbalance in the amount and quality of nutrients consumed (WHO, 2024). The most commonly known categories of malnutrition are stunting (low height-for-age), wasting (low weight-for-height) and undernutrition (low weight-for-age). However, other forms of malnutrition also exist such as obesity, micronutrient deficiency, and a low body mass index (BMI) (Obasohan et al., 2020). The most severe form of malnutrition is commonly identified by under-five child mortality (U5CM), as >50% of under five fatalities is due to malnutrition in Ethiopia (Sahiledengle et al., 2022).

Among children <5 years old, climate change-related malnutrition seems to be the leading cause of child morbidity and mortality (Lieber et al., 2022). The prevalence of malnutrition has slightly decreased in recent years (Belesova et al., 2019). However, trends are currently stable and it is generally believed that the stabilization is associated with the current increase in the number of drought events (UN, 2015). It is expected that an additional number of 10.1 million children will be malnourished by 2050 (Nelson et al., 2009). Progress towards reaching zero hunger in 2050 is still a long way off.

In Ethiopia specifically, malnutrition among children <5 years old is a large problem because this age group is extra vulnerable for developing disease in general (Bain et al., 2013). Moreover, studies indicate that <2 years of age is the most damaging time window for human health (Kwami et al., 2019). For instance, malnutrition among children <5 years old is severely impactful due to multiple socio-economic consequences spanning one's lifetime. For instance, reduced education opportunities and increased risk of infection, metabolic and cardiovascular disease (Salvador et al., 2023; Tirado et al., 2015). Other frequent comorbidities that are associated with malnutrition are malaria, tuberculosis, pneumonia, anemia and hypoglycemia (Girum et al., 2017). Malnutrition among children can even damage their reproductive capacity later in life thereby indirectly impacting the health of offspring (Belesova et al., 2019). In 2017, 45% of the 5.4 million fatalities under 5 years old were attributed to undernutrition (Belesova et al., 2019). In addition to consequences for the individual level, society bears increased health care costs and malnutrition serves as an indication of the general socio-economic performance of a country as a whole (Thiede & Strube, 2020).

The intertwining of malnutrition and climate change is more and more acknowledged (Cooper et al., 2019). Newly emerged terms such as the 'Global Syndemic' have recently gained more popularity in usage by researchers (Swinburn et al., 2019). The Global Syndemic is a term that describes the interaction between undernutrition, obesity and climate change induced extreme weather (Dietz & Pryor, 2022). Despite the increased recognition, and despite the substantial prevalence of malnutrition, and increased severities and frequencies of drought events, research about the impact of drought hazards on malnutrition is rather limited (Bauer & Mburu, 2017; Lieber et al., 2022). An important reason for this is the complex and unexpected nature of drought events making it difficult to study the effect on malnutrition (Delbiso et al., 2017).

So far, a general understanding has been achieved by previous systematic literature reviews on a global scale about the impact of drought on malnutrition, mostly reporting positive associations between

increased drought frequencies and severities and the prevalence of child malnutrition in Sub-Saharan Africa (SSA) (Agostoni et al., 2023; Belesova et al., 2019; Helldèn et al., 2021; Salvador et al., 2023; Stanke et al., 2013; Thiede & Strube, 2020; Tirado et al., 2015). Associations are mainly indirect, via changes in food systems, alterations in food distributions and elevations in food prices (Salvador et al., 2023) and these steps in turn decrease the availability of high quality food for populations (Mirzabaev et al., 2023; Rylander et al., 2013).

Knowledge about drought and child malnutrition is expanding for Ethiopia, but drought and malnutrition are mostly studied separately in (systematic) literature reviews, meaning that papers are either about drought or about malnutrition (Abdulahi et al., 2017; Katoch, 2022; Mohammed et al., 2020; Sahiledengle et al., 2022). Also, drought events rarely occur in isolation, but often co-occur with other hazards such as wild fires, heat waves and episodes of increased air pollution, poverty, disease outbreaks and conflicts. These kind of extreme events are called compound hazards defined as the combined effect of drought with other extreme events that happen at the same time or slightly after (Hao et al., 2022).

Results from papers that studied the relation between drought and malnutrition are inconsistent. On one hand, a positive association was shown for instance in a meta-analysis about the association between drought and child malnutrition meaning a higher wasting prevalence in moderately drought-affected areas compared to areas that were not affected by drought (Delbiso et al., 2017). And for instance, a positive association between drought and malnutrition and child mortality rates was also shown by Lindtjørn (1990), especially among children who have migrated to relief shelters. On the other hand, a reverse effect was shown by Grace et al. (2015) reporting that drought was associated with a higher birth weight. Furthermore, areas with food abundance controversially showed higher levels of stunting indicating that drought is not the only factor of malnutrition onset (Teshome et al., 2009). Lastly, a paper among children in neighboring country Kenya mentioned that relations between drought and malnutrition varied strongly (Bauer & Mburu, 2017).

This calls for clarification of the impact of drought and malnutrition. Specific research gaps mentioned in literature will now be described.

1.2. Research gaps

Compound hazards have gained relatively little attention in previous literature while several studies mention the need to further investigate the impact of drought and its compound hazards (Ebi et al., 2021; Kemajou Njatang et al., 2023; Lazzaroni & Wagner, 2016; Tofu, 2024). Compound hazards potentially exacerbate the harmful effects of drought as a single climate proxy (Mirzabaev et al., 2023). Only two papers summarized the effect of *ecological* compound effect (Ebi et al., 2021; Salvador et al., 2023) and evidence about the combined and dynamic effects of compounding is still under investigation. It could be insightful to further quantify this impact on malnutrition as the existence of compound hazards is a realistic context of droughts and understanding the interplay could help to tweak intervention strategies.

Second, several studies highlight that special attention should be paid to vulnerability factors (Anderko et al., 2020; Belesova et al., 2019; Helldén et al., 2021; Salvador et al., 2023). Lieber et al. (2022) and Belesova et al. (2019) already provided a broad overview of factors underlying one's vulnerability in multiple countries including Ethiopia, but a thorough investigation about Ethiopia is still needed. Moreover, previous studies mostly focus on specific age ranges (e.g. 12-23 months) (Sahiledengle et al., 2022), but this thesis focuses on all ages below 5 years.

Third, the effectiveness of malnutrition interventions specifically conducted in a drought context needs to be researched in more detail (Mirzabaev et al., 2023). Currently, there is only little evidence (Helldén et al., 2021; Marshall et al., 2021; Salvador et al., 2023; Shiferaw et al., 2014). Existing evidence so far is mainly focused on general improvement of nutritional education and feeding programs.

Contributions to existing systematic reviews such as key papers (Belesova et al., 2019; Lieber et al., 2022) are the focus on a more narrow study area and target population making it possible to do a more in depth

analysis of literature including more up to date literature considering quantitative outcomes as well. Also, Salvador et al. (2020 & 2023) already investigated socio-economic risk factors and interventions but these studies were 1.) not using a systematic literature review design and were 2.) not specifically focused on malnutrition but on a variety of diseases.

1.3. Aim and objective

This thesis aims to identify the impact of drought on malnutrition among children age <5 years in Ethiopia, with special focus on:

1.) Impact of drought (as single effect and combined with ecological compound hazards) on malnutrition prevalence. There will only be focus on *ecological* compound hazards, to limit the scope of this thesis.
2.) Socio-economic factors associated with drought-induced malnutrition.
3.) Interventions that reduce child malnutrition prevalence after or during drought events.

This will be done by investigating quantitative and qualitative metrics of the association between drought and child malnutrition, by linking the sequence, duration and severity of drought and compounding hazards to child malnutrition, by describing all socio-economic factors underlying drought-related malnutrition and by comparing qualitative and quantitative effect measures of interventions in relation with drought and malnutrition.

The final product will be a systematic description of effect measures (when available) of the impact of drought on child malnutrition and an descriptive overview of vulnerability factors. Additionally, policy recommendations for effective interventions will be provided.

1.4. Research question

> What is the impact of drought on malnutrition among children under five in Ethiopia?

Sub questions:

- What are the physical impacts of drought and ecological compound hazards in relation to child malnutrition?
- Which socio-economic factors are underlying child malnutrition vulnerability?
- What are effective interventions that reduce child malnutrition during drought events?

2. Theoretical background

2.1. Study area

Ethiopia is one of the 54 countries in SSA. Ethiopia spans a total surface area of 1.1 km^2 (The World Bank, 2024), has a population count of >129 million (Database.earth, 2024) and has an annual population growth of >3 million (Database.earth, 2024). Ethiopia is located in the Horn of Africa and lies alongside Eritrea, Somalia and Djibouti. It is located in close proximity to the Gulf of Aden. Ethiopia is subdivided into 9 regions: Afar, Amhara, Tigray, Dire Dawa, Somali, Oromia, Southern nations, nationalities' and peoples (SNNP), Benishangul-Gumaz and Gambela (Habtewold et al., 2019) (Figure 1). Furthermore, several climate zones with corresponding vegetation types exist in Ethiopia. In the mountains (Amhara, Oromia, SNNP, and Tigray), the dominant type of vegetation is Afroalpine, while in the lowlands (Afar and Somali), there is more semi-arid and arid kind of vegetation (Asefa et al., 2020). A detailed description of vegetation types is described in previous literature (Asefa et al., 2020). Ethiopia has 3 main seasons: belg (small rain season, Feb-May), bega (dry season, Oct-Jan) and kiremt/meher (main rain season, Jun-Sep (JJAS)). Most rain falls during kiremt/meher (Dimitrova, 2021).

Ethiopia is divided into highland in the Northwest (43% of the surface) and lowland in the Southeast (Lemessa & Perault, 2001). The highlands are characterized by higher annual rainfall levels compared to the lowlands. It is not without reason that pastoralist communities are widespread located in the lowlands that are drought prone as a consequence of the systematically lower rainfall. Pastoralism namely originated from an adaptation response to low rainfall circumstances. The result was that pastoralists are keeping livestock only, a type of livelihood that relies on lower rainfall than agriculture (Haddis, 2018). Despite this adaptation capacity, pastoralist communities are dealing with increased extreme climate conditions and this stresses the sustainability of their way of living.

In contrast to pastoralists, agriculturalist, also known as croppers, are highly dependent on rainfall because they are specialized in rainfed crop production (Sinore & Wang, 2024). This is one of the reasons why Ethiopia is highly vulnerable for natural hazards such as drought shocks. 84% percent of people living in Ethiopia is namely employed within the agricultural sector (Meskele et al., 2023). Most agriculturalist still lack advanced irrigation techniques and rely on indigenous knowledge and traditional farm techniques instead. This explains their vulnerability to drought. More about vulnerability in following paragraphs. Both agriculturalist and pastoralists are mostly small hold farmers. Mixes of agriculturists and pastoralists, named agro-pastoralists, also live in Ethiopia and this type combines livestock and crop production.

Figure 1. *9 Regions in Ethiopia and the type of livelihood* (Bolongaita et al., 2022).

2.2. Drought in Ethiopia

According to the WHO, drought can be defined as a prolonged dry period with reduced precipitation (WHO, 2019). Other definitions of drought are that both a reduced mean precipitation level and increased temperature should be experienced within a certain region and time (Coffel et al., 2019; Kourouma et al., 2022) (Figure 2). Drought develops from months to years (Mera, 2018). Different definitions for drought and multiple indices to quantify drought exist. I refer to (Mukherjee et al., 2018) for more information about this. In this thesis, there will be adhered to drought as a deviation in rainfall or temp from average levels, or expressed by another relevant drought index.

In Ethiopia, drought is characterized by precipitation levels lower than 30-50% of normal seasonal rainfall (Mera, 2018). However, any description of drought shock, event, or deviation will be considered in this thesis as long as these refer to conditions more extreme than 'just' seasonal fluctuations in drought severity and frequency or climate variability. Normal fluctuations in drought is a natural phenomena caused by amongst other El Niño–Southern Oscillation (ENSO), but will not be explained further in this thesis (Ekolu et al., 2022).

Frequencies and severities of drought are currently increasing due to climate change (Salvador et al., 2023). People notice this by longer and more severe drought episodes during the year. Climate change is on one hand driven by *anthropogenic* factors such as GHG emissions. On the other hand, *natural* changes in precipitation patterns and water-related disasters occurrences have an impact on drought events. Several droughts have already been experienced by Ethiopians throughout history at least in years 1965, 1969, 1973, 1983, 1987, 1989, 1997, 1998, 1999, 2003, 2005, 2008, 2009, 2012, 2015 (Kourouma et al., 2022). 2002–'03, 1984–'85, 1988–'89 and 2015 are considered the most severe droughts of the last decade (Kourouma et al., 2022; Suryabhagavan, 2017). Drought events are expected to increase substantially in the 21th century (Stanke et al., 2013).

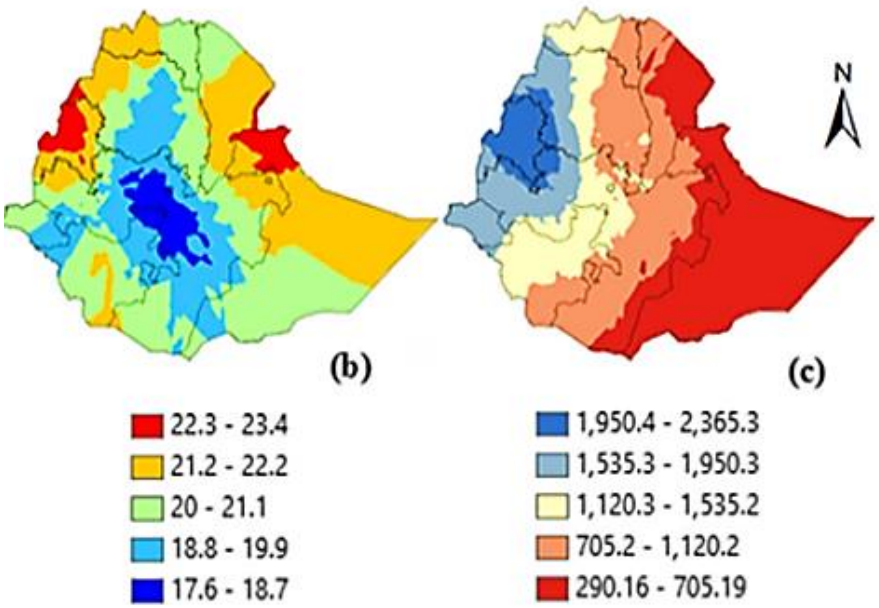

Figure 2. *Mean annual temperature in degrees Celsius (A) and rainfall in mm in Ethiopia (B)* (Kassaye et al., 2021).

2.3. Malnutrition

Malnutrition can be defined as having excess, deficiency or an imbalance in the amount and quality of nutrients consumed (WHO, 2024). The three main categories of malnutrition are *stunting (*chronic malnutrition, takes several months to years, insufficient nutrient intake related to energy needs), *wasting (*acute malnutrition over shorter time period takes <3 months) and *undernutrition* (insufficient nutrient intake that can be caloric or micronutrient deficiencies) (Belesova et al., 2019). Stunting, wasting and undernutrition are commonly determined by height-for-age Z-scores (HAZ), weight-for-height Z-scores (WHZ) and weight-for-age Z-scores (WAZ), respectively. Z-scores can be interpreted as child height and weight relative to well-nourished children of the same age and sex (Hirvonen et al., 2020). In 2019, 37% of children under five were stunted, 7% wasted, and 21% underweight (Bidira et al., 2021). A spatial overview of the WAZ <2SD for Ethiopia and other African countries is shown in Figure 3.

Other malnutrition metrics are: BMI, birth weight, fetal growth restriction, anemia, low birth weight, dehydration, middle-upper arm circumference (MUAC) and U5CM (Phalkey et al., 2015). Regarding the latter, >45% of U5CM is due to malnutrition and therefore U5CM is an important indicator of malnutrition severity, despite it's indirect nature (Berhanu et al., 2018). Malnutrition has consequences on the short term (mortality, morbidity, disability) and long term (adult size, intellectual ability, economic productivity, reproductive performance, metabolic and cardiovascular diseases) (Figure 5) (Salvador et al., 2023; Tirado et al., 2015).

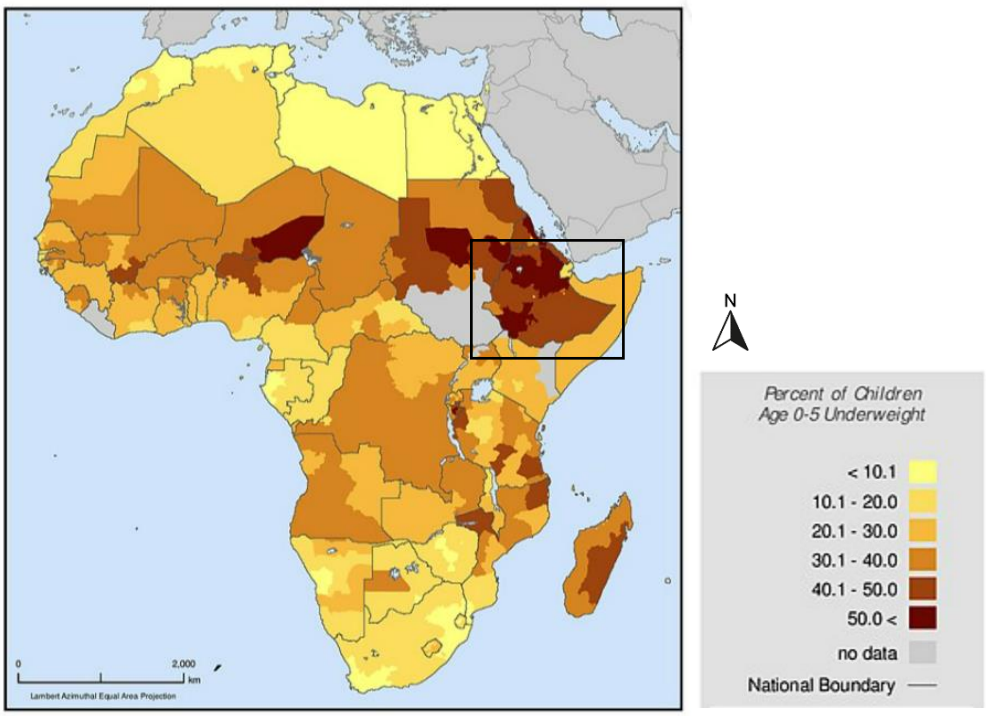

Figure 3. *Child malnutrition prevalence (WAZ <2SD below the median)* (NASA, 2005)

2.4. Pathways how drought impacts malnutrition prevalence

It takes on average 3 months before the effect of climate change is visible on malnutrition prevalence (Grace et al., 2015; Randell et al., 2020). Drought induced impacts on malnutrition are mainly via indirect mechanisms (Salvador et al., 2023). The most important examples are:

1.) *Reduced water quantity and quality and or sanitation and hygiene (WASH) facilities*. Dehydration can occur due to lack of clean drinking water. Furthermore, reduced water quantity and quality impacts agricultural purposes and risks food production,

2.) *Increased incidences of vector borne illnesses* such as malaria, diarrhea and tuberculosis make children vulnerable for malnutrition,

3.) *Intensification of extreme heat events, wildfires, dust storms, air pollution.* These events in turn damage cropland and water quality,

4.) Impacts on agriculture and thereby putting pressure on food security,

5.) *Damage to natural ecosystems* such as the disappearance of certain animal species, change of soil moisture and water influx by rivers and lakes that in turn impact agriculture and food security.

Other indirect examples that are given in literature are *livestock death*, *damage to fodder* and *price spikes,* (decreasing households ability to buy food) and *migration* (Tofu, 2024). Migration movements towards areas with higher water qualities and quantities cause loose of resilience of these attractive areas as more people concentrate in these areas (Ibrahim & Mensah, 2022). E.g. more than 88% of the population lives on more than 1500 meters (Lemessa & Perault, 2001). For the sake of clarity, Figure 4 describes a conceptual framework adapted from (Randell et al., 2020) that gives a broad overview of the mechanisms linking drought and stunting.

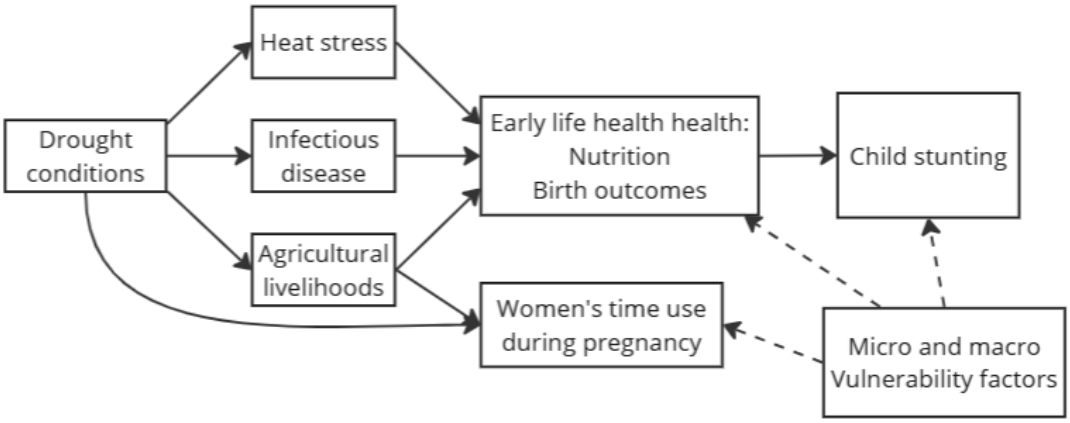

Figure 4. *General pathways between drought and malnutrition*. Adapted from (Randell et al., 2020).

2.5. Vulnerability

Vulnerability to drought depends on 3 pillars: *sensitivity* (is the study area a drought prone area), *exposure* (drought severity and frequency) and *adaptive capacity* (socio-economic factors, livelihood strategies, dependence on livestock, social safety network, health water access, finance) (Salvador et al., 2023; Tofu, 2024). In other words, vulnerability is determined by house hold, community and individual risk factors (Kasaye et al., 2019).

Children under five years old in SSA are particularly vulnerable for developing malnutrition. This has to do with the fact that 1.) Africa is more climate sensitive than the average worldwide (Bain et al., 2013) – Large parts of land in SSA are vulnerable for desertification (a transition to dryer land) (Ebi et al., 2021), 2.) that there are low health care facilities, 3.) that these children already have a poor nutritional status – already existing health problems such as infection disease and poor sanitation facilities increase the risk of child malnutrition., 4.) that there is corruption 5.) that there is lack of action to reduce malnutrition by the African government, 6.) that there is low a GDP, 7.) that there is a high crop yield demand (and a 150-228% increase expected in 2050), 8.) that there is high reliance on rain-fed agriculture in SSA (85% of water used for agricultural purposes), 9.) that small holders lack malnutrition adoption capacities (Azadi et al., 2022; Bain et al., 2013). As mentioned, vulnerability factors have been researched, but systematic reporting is limited (Belesova et al., 2019).

2.6 Interventions

Research about strategies to combat the impact of drought on malnutrition is ongoing. Effective strategies are still to be investigated and this explains the lack of protocols in place in Ethiopia (Usman et al., 2019). Most research so far has mainly focused on either drought-related interventions or malnutrition-related interventions, meaning studied separately (Bitew et al., 2020; Gezmu et al., 2023; T. C. Mekonnen et al., 2022). Only occasionally, malnutrition interventions specifically during or directly after drought events have been assessed for its effectiveness. Interventions can be categorized by sensitive (focus on underlying issues e.g. poverty) and specific interventions (e.g. directly targeting food security) (Khalid et al., 2019). So far interventions have mostly been specific instead of sensitive such as supporting the livelihood of rural households, promoting gender equality and nutrition education (Mekonnen et al., 2022).

For a time line of previous nutrition programs implemented so far between 1990 and 2015, I refer to (Ruducha et al., 2017), in which the program type and the year of implementation is listed. An example of an intervention implemented after 2015 is described by Smith & Frankenberger (2022) namely comprehensive resilience programming (CRP). Main options for interventions so far are described in (Figure 5) based on (Salvador et al., 2023).

2.7. Conceptual framework

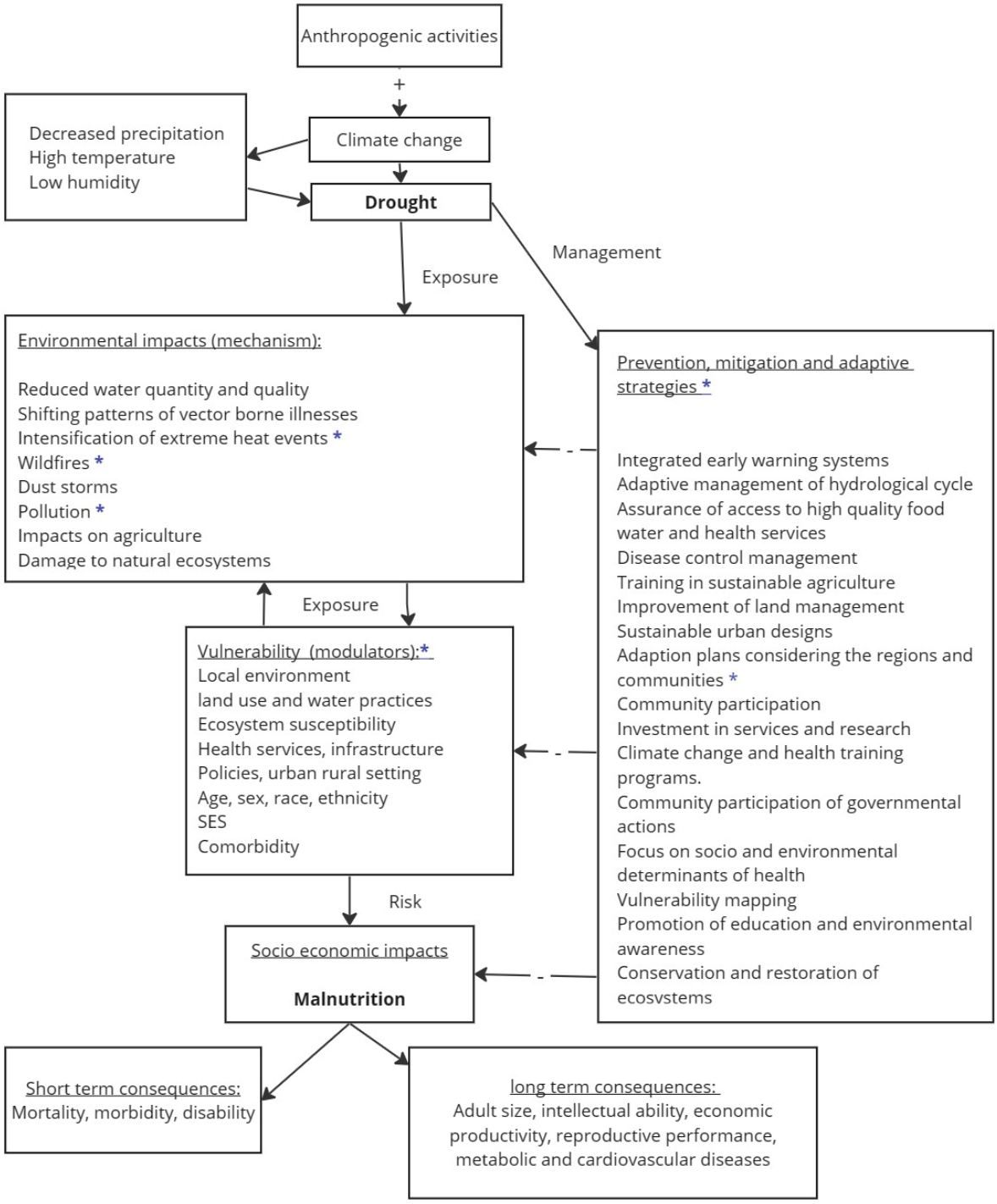

Figure 5: *Conceptual framework of all contextual factors that play a role in the association between drought and malnutrition*. Asterix indicate research gaps addressed in this thesis. Framework adapted from (Salvador et al., 2023; Tirado et al., 2015).

3. Methodology

3.1. Rational for choosing study design

A systematic literature review following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021) was conducted. This methodological study design was chosen because this type of design allows integration of results from multiple sources and this is preferred since the impact of drought on malnutrition is inherently complex. Moreover, systematic literature reviews create evidence with the highest strength, reduce the risk of overlooking important papers, minimize effects of selection and publication bias and include risk of bias (ROB) assessments (Ho, 2021; Nightingale, 2009).

3.2. Switching from SSA to Ethiopia

Initially, this thesis aimed to investigate the impact of drought on child malnutrition in SSA. Therefore, the first part of the screening was conducted focusing on all countries in SSA. The rational for switching to Ethiopia only for the second part of the screening is because screening >5000 papers was undoable timewise. Why Ethiopia: papers about Ethiopia were relatively abundant compared to other SSA countries and therefore the research question remained researchable. Moreover, countries in SSA are still quite heterogenous as SSA spans a large area. Therefore, estimations of drought impacts on malnutrition and recommendations for mitigation and adaptation strategies for countries within SSA combined might not be less insightful. Instead, it was presumed more valuable to focus on Ethiopia only.

3.3. Study selection

First a broad search approach was applied to get a general understanding of research gaps. Formulation of the final search term was based on previous literature and informal searching using Mesh terms, keywords and free-text terms (title and abstract). Search terms were created per sub question. An example of the final search term for use in PubMed can be found in (appendix A). Besides using search terms, reference lists of key papers were hand searched because Lieber et al. (2022) specifically mentioned the potential added value of this strategy in finding literature.

The following literature data bases were used: PubMed, Scholar, Web of Science and African Journals Online. Using four literature data bases was assumed to be enough as the minimum number of literature data bases to be used in systematic literature reviews is 2 (Higgins et al., 2023). Grey literature was excluded as previous research did not found substantial differences in results between scientific and grey literature. Searching for studies was continued until data satisfaction was met.

Duplicates and studies that did not meet inclusion criteria were removed. The search strategy was documented using a Log book to note excluded papers with reasons to do so (appendix B). References were saved and categorized in a citation manager.

3.4. Inclusion criteria

- Peer-reviewed primary and secondary papers published between 2000–2024.
- English language.
- Both quantitative and qualitative metrics.
- Children <5 y/o or mother-child pairs or child-household relations living in Ethiopia.
- Depending on the sub question, an explicit link between:
  A.) Drought and malnutrition and its impact, or
  B.) Explicit link between drought, malnutrition and ecological compound hazards including wild fires, air pollution and heat waves, or
  C.) Explicit description of interventions to reduce malnutrition prevalence in a drought context.
  Drought, ecological compound hazards and interventions defined as indicated by the primary source. Child malnutrition should be diagnosed by at least one form of clinically anthropogenically identified malnutrition status.

- The outcome should be investigated in relation to explicitly mentioned drought event, drought shock or drought famine, or an effect measure of drought should be described.

3.5. Exclusion criteria

- Abstracts only.
- Reviews, modeling papers, opinion articles, editorials.
- Malnutrition diagnosed due to infection or autoimmune disease.
- Meaning of drought that is unrelated to climate.
- Studies conducted in drought-prone areas in general.
- Data from Ethiopia but not studied separately.
- Drought defined as access to a water source, improved water quality, or distance to water.
- Malnutrition status due to infection disease.
- Malnutrition defined by undernourishment, food security, dietary diversity or food intake.
- Mortality not linked to malnutrition.

The full description of in and exclusion criteria is provided in (appendix C).

3.6. Data extraction

Once papers were selected that met inclusion criteria, a summarizing table was created with the following characteristics: first author(s) and year of publication, geographical location, type and age of sample, N, data source, study context, drought event characteristics, research objective, exposure(s), outcome(s), study design, control data availability, data collection period and lastly key results (appendix D).

Most categories in the table are self-explanatory but some deserve some extra explanation. For study context, underlying trends were described the during the data collection period such as the presence of, conflicts, poverty of other compound hazards as mentioned by the papers. For category drought event characteristics, a description of the drought event (year, temp, precipitation timing etc.) was provided. For exposure, the drought effect measure was described (when available), or it was mentioned that the study was conducted in specific drought context. For outcome, at least one child malnutrition metric was described.

Main risk factors and interventions where identified only when there were explicit modifiers mentioned in the paper or when there were explicit interventions mentioned in the context of drought and malnutrition, respectively. Interventions and risk factors were only taken into account when they were main topics of the papers, or mentioned specifically. In this thesis, WASH interventions were not taken into account as numerous studies already focused on this and because of the close relation with infection disease that could alter results.

3.7. Data analysis

Papers were categorized according to similar metrics and topics. Meta-analyses were conducted in case when a sufficient number of included studies had control data available and when the heterogeneity of studies was limited. Data was considered as control data when a study population under similar conditions experienced a no drought, or no intervention condition. This is different from for instance comparing drought-affected and non drought-affected areas in Ethiopia.

3.8. Risk of bias assessment

A risk of bias (ROB) assessment based on (Johnson et al., 2014) was performed for all included papers. This ROB assessment was also applied in (Belesova et al., 2019). Researchers should try to minimize bias because this can disturb study results (Higgins et al., n.d.). For instance, a high risk of bias indicates that results from this study should be interpreted with caution. A ROB assessment is a standard procedure of systematic literature reviews adhering to PRISMA guidelines. Several domains of individual studies are assessed for bias

which can be high, low, probably high, probably low, unclear or not applicable (Cochrane, n.d.). The seven domains that were assessed were:

1.) *Recruitment strategy* - consistent sampling and recruitment among participants?

2.) *Blinding* - effort done to prevent participants from knowing study outcomes?

3.) *Exposure assessment* - robust drought metric reported?

4.) *Confounding* - adequate reporting of factors that might the alter the association between drought and malnutrition?

5.) *Outcome data* - is the malnutrition metric robust?

6.) *Selective reporting* - are papers free from hiding specific results?

7.) *Conflict of interest* - absence of stakeholder engagement with financial interest in study outcomes?

Different from (Johnson et al 2014), domain 'other bias', was removed because of this relatively broad and arbitrary domain. Full descriptions of the criteria for the ROB assessment and the summaries of assessments can be found in (appendix E and F).

Example assessment domain 'incomplete outcome data':

Dimitrova et al., 2021

Assessment: low risk of bias.
Explanation: Standardized measures are used, weight-for-height Z-scores, against the WHO guidelines.

Doocy et al 2005

Assessment: probably low risk of bias.
Explanation: It is described that MUAC is acceptable, and a more practical measure comparable to BMI (Semba & Bloem, 2001). Cut-off values are provided which suggest that this is a reliable metric to use. Cooping capacity was self reported.

Kaluski et al., 2002

Assessment: high risk of bias.
Explanation: Standard cut-off values are used for a few malnutrition metrics, but not for all. Not referred to WHO or other source. Sometimes, the author referred to percentages instead of Z-scores (inconsistent).

Thereafter, an overall ROB was provided based on table 8.2.b described in the Cochrane handbook (Higgins et al., n.d.):

1.) *Low risk of bias* - all domains are assessed (probably) low risk of bias.
2.) *High risk of bias* - at least 1/7 domains assessed as (probably) high risk of bias.
3.) *Some concerns* - everything else.

Note: 1 domain or more assessed 'unclear' while all other domains (probably) low risk: some concerns.

Note: Not applicable is not considered in the summation of total ROB score.

Interpretation bias regarding the ROB assessment was minimized by relying on a second reviewer.

4. Results

4.1. Study selection

In Figure 6, an overview of the study selection is provided. Initially, >5000 records were identified when there was focused on SSA. After limiting the scope to Ethiopia and removing duplicates, 2656 records remained for title and abstract screening. 202 records were eligible for full text screening. 38 papers were added through handsearching. Finally, 17 papers were included. Reasons for exclusion of records during the full-text screening are provided in (appendix B).

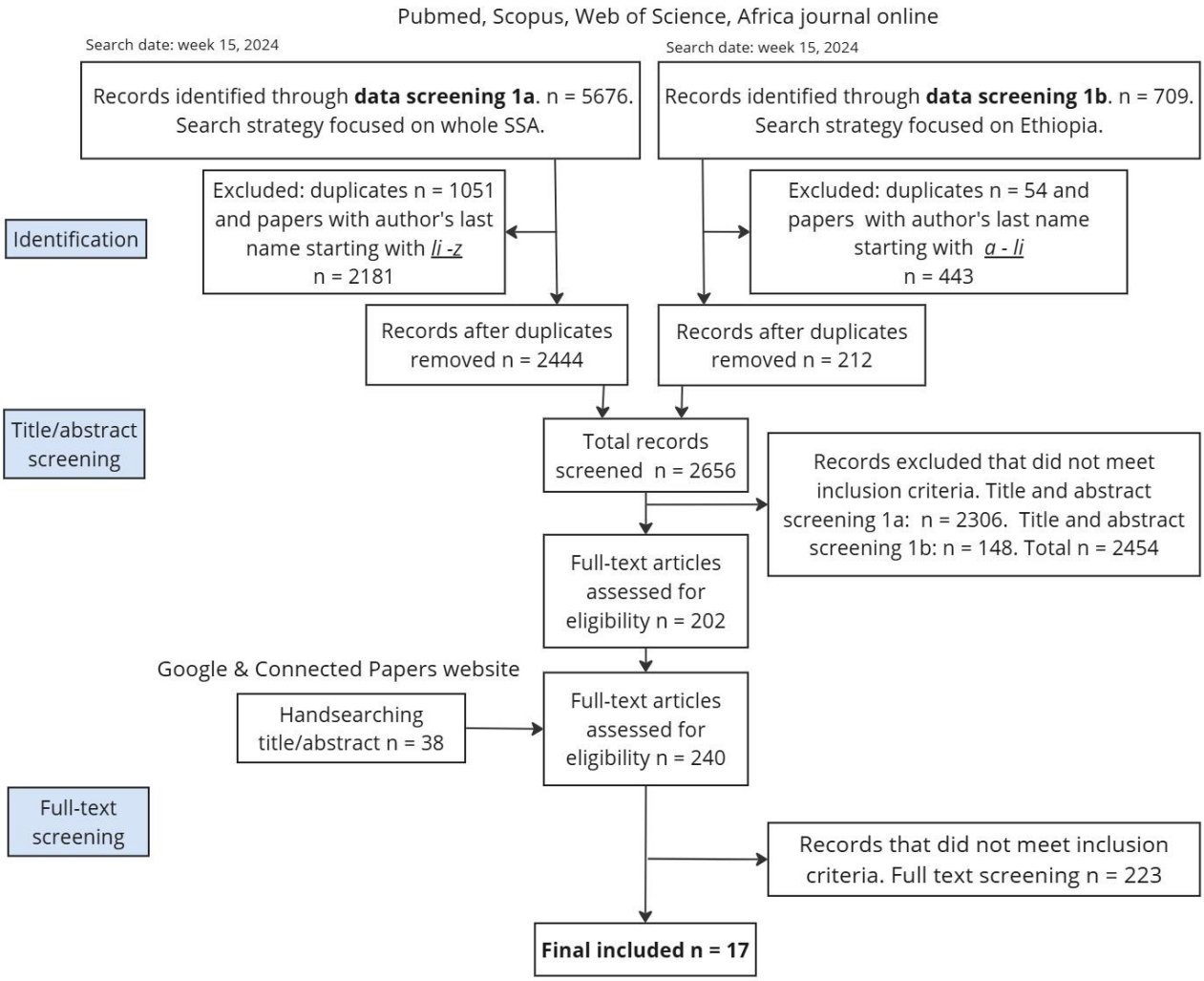

Figure 6. *Study selection flowchart*. Note: the scope (1a, Sub-Saharan Africa) was too broad to be feasible to investigate within 3 months. Therefore, the last 2181 studies in screening 1a were not assessed. Instead, screening 1b continued narrowing the scope to Ethiopia only. From these 2181 studies initially excluded in 1a, 709 were assessed in 1b.

4.2. Study characteristics

Of the 17 included studies published between 2001 and 2022, only (n=2) had a control condition (Table 1). Therefore, a meta-analysis was not conducted. Drought was mostly reported by rainfall deviations (n=7), followed by drought as study context (n=6) and by drought subjectively reported in surveys (n=5). Most

studies provided WHZ (wasting) (n=13) and HAZ (stunting) metrics (n=10). Oromia (n=10), Amhara (n=8) and SNNP (n=8) were the regions most represented. Studies included mostly mixed or unclear types of livelihood, idem for agro-ecology.

Table 1. *Overview of study characteristics from the 17 included studies.* Note: numbers add up to >17 because papers can have multiple characteristics. Abbreviations: SPEI, standardized precipitation evapotranspiration index; NVDI, Normalized Difference Vegetation Index; WAZ, weight-for-age Z-score; HAZ, height-for-age Z-score; WHZ, weight-for-height Z-score; BMI, body mass index.

	No. of studies		No. of studies
Study design		**Livelihood**	
longitudinal study, no control	4	Agriculturalists	3
Longitudinal, with control	1	Pastoralists	1
Cross sectional, no control	5	Mix/both	6
Cross sectional, with control	1	Unclear	6
Cross sectional repeated measures, no control	4		
Cross sectional repeated measures, control	2		
Drought exposure		**Region**	
Drought as study context	6	Afar	3
Rainfall deviations	7	Amhara	8
Temperature deviations	1	Tigray	7
SPEI deviations	1	Somali	6
NDVI deviations	1	Oromia	10
Drought reported by household in survey	5	SNNP	8
Drought scale or binary shock	1	Benishangul-Gumaz	4
		Gambela	3
		Unclear which regions specifically	5
Malnutrition outcome		**Agro-ecology**	
WAZ	4	Highlands	4
WHZ	13	Lowlands	1
HAZ	10	Mix/both	4
Mortality	3	Not specified	6
Micronutrient deficiency	1		
BMI, growth/height, anemia	4		

Characteristics per study are described in (appendix D). All studies 1.) were observational in nature, 2.) included participants <5 years old, 3.) had at least one drought malnutrition metric, 4.) and were conducted within a drought hazard context or quantified drought by utilizing a climate proxy. Generally, studies were heterogenous regarding the number of participants, quantifications or descriptions of drought events, malnutrition metrics and study contexts.

Two studies contained the same data source (Chotard et al., 2010; Mason et al., 2010). 6 studies also included data about other countries than Ethiopia. Most studies specified study regions and sometimes even villages within regions. Generally, household data came from household surveys, drought data from meteorological databases. The number of included children ranged from 145 to 4816. Kaluski et al. (2002) potentially included even more participants (n = 10449), but that was unclearly described in this study.

Not all studies provided details about the study context such as the existence of compound hazards. When available, details were provided in appendix D. *Ecological* compound hazards were not identified. However, examples of main other compound hazards that were mentioned are conflicts (n=6), measles outbreak (n=2), poverty (n=1), malaria outbreak (n=1), high population density (n=1), political instability such as demonstrations (n=1) and poor health infrastructure (n=1). Studies were often affected by multiple hazards instead of single hazards: e.g. military offensives, aerial bombardment of markets, damage to livestock and crops were all present in (Dercon & Porter, 2014). Another example is Kaluski et al. (2002) with poverty & conflicts, or De Waal et al. (2006) who mentioned the presence multiple structural chronical conditions.

Regarding papers that documented the number of people affected, at least 10 million people were affected (range 8-13 million) in a subset of studies. Some also documented the average rain or max temperature differences during a drought compared to normal. For instance, a difference of about 200 mm annual rainfall and 2 degrees Celsius, respectively. Drought was reported in the following years: 2015/2016; 2015 (2x); 2000 & 2005/2006; 1984/1985; 2002/2003 (2x); 1997-2000; 1998/1999; 2011/2013; 2000/2005; 2014-2017; multiple 2011/12 & 2013/14 & 2015/16; 1996–2004; 1999/2000.

4.3. Impact of drought and physical factors on malnutrition

Results about the impact of drought will now be described for the following categories: stunting, wasting, underweight, micronutrient deficiency and anemia, growth and BMI and lastly mortality. Also, the impact of the combined effect of drought with ecological compounding hazards will be described. And there will be categorization according to drought metric and year. Furthermore, some indication of the risk of bias per paper will be provided throughout this chapter already, but for results of the full assessment I refer to chapter 4.6. To maintain an overview, a summarizing sentence of main findings will be provided after larger paragraphs.

Stunting (HAZ)

Of the 17 included studies, 9 articles reported stunting metrics. Significant detrimental impact of drought on stunting was shown by 6 papers (Bakhtsiyarava & Grace, 2021; De Waal et al., 2006; Dimitrova, 2021; Gari et al., 2017; Georgiadis et al., 2021; Kaluski et al., 2002). Bakhtsiyarava & Grace (2021), De Waal et al. (2006) and Kaluski et al. (2002) had high risk of bias and results from these papers should therefore be interpreted with caution. Three main papers are selected as examples of the detrimental impact on malnutrition: Bakhtsiyarava & Grace (2021) reported that at average farm production diversity, children from areas that received less than normal rainfall have sign lower HAZ (−0.124, p=0.048). Gari et al. (2017) reported that the prevalence of HAZ less than 2SD was 44.8% in 2014, and increased to 50.7% in 2015 (P<0.001). Dimitrova (2021) showed that drought exposure under five is significantly associated with stunting during childhood. The share of stunted children aged 0–5 years increased by 3% points (p<0.01) after drought, other variables held constant. At age 2 and above, the prevalence of stunting is still 4% points higher when exposed to drought in infancy (age 0-2 y).

Other than a positive association, three papers showed a nuanced or lack of association between drought and malnutrition (Hagos et al., 2014; Hirvonen et al., 2020; Tesfaye, 2022). Namely, Hirvonen et al. (2020) showed a detrimental impact of the 2015 drought on stunting HAZ (more negative HAZ score). However this association was not significant. In this same article, nearly flat regression lines were seen between drought and not drought exposed areas implying that children residing in drought exposed areas did not have worse HAZ scores in 2016 compared to children who were not (or were less) exposed to the 2015 drought. Hagos et al. (2014) on the other hand, showed inconclusive results. This paper was assessed with high risk of bias and results of this paper should therefore be considered with caution. Hagos et al (2014) reported that rainfall and temperature partly predict variations in child stunting (and underweight). One SD increase in rainfall leads to 0.242 SD increase in moderate stunting (sign). One SD increase temperature leads to 0.216 SD decrease in moderate stunting (sign). Results were variable among different agroecological zones. Lastly, Tesfaye (2022) showed that drought had no impact on crop interventions intended to reduce stunting suggesting that drought had no detrimental impact but rather a neutral impact.

Summary: most of the studies (n=6) reported a significant increase in stunting prevalence after drought. However, one study reported a significant decrease in malnutrition after drought exposure, one study showed a detrimental but non significant association and one study showed a neutral association. There were studies with high risk of bias.

Wasting (WHZ and MUAC)

11/17 studies reported wasting metrics. Only three studies showed a *significant* impact of drought on wasting, 2 of them suggested a detrimental impact, meaning a higher prevalence of wasting (Chotard et al., 2010; D. K. Mekonnen et al., 2022) and one suggested a negative impact meaning a lower prevalence of wasting after drought (Gari et al., 2017). The two studies with detrimental impact were both assessed with high risk of bias. Chotard et al. (2010) reported the years 2000 and 2005–06 of drought were associated with an increase in wasting: 8.7% point increase in wasting between 2000 and 2004 (2004 is reference year, no drought) adjusted for country year and season. 6.9% points for 2006 compared to 2004, with adjustment for livelihood and season. These percentages (8.7 and 6.9%) are more extreme than normal average seasonal fluctuations of 5% point (no sign levels provided), suggesting that drought has an impact on wasting. (Mekonnen et al., 2022) reported that if drought occurred (binary 1/0), than there was a 0.155 higher prevalence of wasting ($p<0.05$). On the other hand, Gari et al. (2017) (low risk of bias) showed that the prevalence of WHZ decreased instead of increased, namely from 7.3% in 2014 to 4.1% in 2015 ($P<0.001$).

In contrast, *no sign* impact was reported by five papers (Bakhtsiyarava & Grace, 2021; Dimitrova, 2021; Hirvonen et al., 2020; Ledlie et al., 2018; Tesfaye, 2022). For example, impacts of drought on WHZ was -0.068, but not significant (Hirvonen et al., 2020). Regressions also showed a relatively flat relationship between WHZ and rainfall Z-scores. Bakhtsiyarava & Grace (2021) (the only paper of those five with high risk of bias) reported that at average farm production diversity, no significant difference was seen in WHZ between children from areas that received less than normal rainfall compared to normal conditions. The last example is Ledlie et al. (2018), who reported no significant results of rainfall shock on wasting. Coefficients were also small.

Doocy et al. (2005) and Salama et al. (2001) were other papers that reported wasting metrics. Despite that both these papers reported prevalence of malnutrition in a drought context, it was not insightful to compare these studies as both were conducted during different drought events (2002/2003 vs 1999/2000 and used different outcome metrics (MUAC vs WHZ), respectively.

Summary: *Only three studies showed a significant impact of drought on wasting, two of them suggested a higher prevalence of wasting (Chotard et al., 2010; D. K. Mekonnen et al., 2022) and one suggested a lower prevalence of wasting (Gari et al., 2017). No significant impact was seen by five papers. There were papers with high risk of bias.*

Underweight (WAZ)

Two papers (Gari et al., 2017; Haileamlak, 2003) reported underweight metrics, the former assessed with low risk of bias, the latter with high risk of bias. Haileamlak (2003) reported that 64% of children under five was severely underweight (WAZ<60%) during drought. Unfortunately, no control was available. Gari et al. (2017) reported that the WAZ prevalence was 18.5% in 2014, and 15.4% in 2015 ($P<0.001$).

Micronutrient deficiency and anemia

Gari et al. (2017) showed that the prevalence of anemia was 28.2% (95% CI: 26.6-29.8) in 2014 and increased to 36.8% (95% CI, 35.1-38.5) in 2015 ($P<0.001$). Kaluski et al. (2002) provided limited details of micro and macro nutrients to be able to meaningful assess the impact of drought.

Growth and BMI

Dercon & Porter (2014) (High risk of bias) reported a 5.3 cm shorter height compared to peers that were not affected by drought when they were 12-36 months of age. There was no significant impact of shock on other age groups. No significant results were reported for children exposed to drought in utero and the impact on

their height later in life. The coefficient is negative, but non significant. Lastly, regressions on BMI in this study were not significant.

Mortality

Mortality was investigated in 4/17 papers (De Waal et al., 2006; Haileamlak, 2003; Mason et al., 2010; Salama et al., 2001). It was complicated to give an overall result of the impact of drought on mortality as the three papers quantified and described the effect on mortality quite differently and variable mortality rates were found in these studies. Haileamlak (2003) showed that 23% of the WAZ + edema cases died (in drought context, no control). Salama et al. (2001) showed that 72.3% of mortality under five was due to wasting (in drought context, no control). De Waal et al. (2006) showed that mortality rates were higher in drought affected areas, namely 158 death per 1000 vs 121 per 1000, but the increased mortality rate was not necessarily due to malnutrition but potentially due to interplay of chronic hazard events and high levels of malnutrition historically in this region. Drought in 2002-2003 did not have a significant marginal effect on mortality (coefficient 0.00241 p=0.802). Mason et al. (2010) reported that drought was associated with higher U5MR.

Summary: generally an increased impact on malnutrition prevalence was identified, but variable outcome types were used (% vs odds) there was lack of control and interplay with contextual chronic other drivers in the area.

Ecological compound hazards

0/17 studies explicitly investigated ecological compounding hazards. However, three studies about drought and ecological compound hazard heat wave were identified during the study selection phase of this thesis (Coffel et al., 2019; Grace et al., 2015; Lesk et al., 2022), However, these were excluded because of reporting the outcome metric agricultural crop yield instead of malnutrition, being a scenario analysis and being a review, respectively. Grace et al. (2015) indicated only a small decrease in birth weight (4.3%) due to the combined effect of heat waves and precipitation effects. Lesk et al. (2022) investigated the combined impact of heat waves and drought and that resulted in about 30% crop loss. In contrast, the same paper also mentioned that the combined effect could have mitigated impacts. Coffel et al. (2019) showed poor crop yield due to combined effects of drought and heat waves.

Summary: 0/17 studies explicitly investigated ecological compounding hazards.

Rainfall deficiency

The drought category that was most represented was rainfall deviations reported by seven studies and therefore an attempt was done to investigate whether a certain similar trend could be identified on malnutrition (Bakhtsiyarava & Grace, 2021; Dercon & Porter, 2014; Georgiadis et al., 2021; Hagos et al., 2014; Hirvonen et al., 2020; Ledlie et al., 2018; Tesfaye, 2022). Rainfall deviations in these studies ranged from: anomalies of more than -2SD below the long-term (1981–2016) average, rain shortfall in 1984–1985 compared to the ten year mean, deviations from long-run community and season combined average and year-specific average, SD increase in rainfall data (JJAS), annual rainfall below −2 SD (JJAS), number of SD Rainfall below the 13-year average mean (JJAS), Rainfall data extracted from 2001-2015 to calculate the historical average and SD of rainfall a proxy for long-term rainfall variability. Since these definitions of rainfall deviations are heterogeneous, it hard to give estimate an overall trend. Variable results were reported, ranging from a lower prevalence, a higher prevalence to no significant effect at all. An example for each of those will be provided next. At average farm production diversity, children from areas that received less than normal rainfall have significant *lower* HAZ (−0.124, P<0.05) (Bakhtsiyarava & Grace, 2021). On the contrary, Hagos 2014 showed that one SD increase in rainfall significantly *increases* moderate stunting with 0.242 SD. Moderate wasting and underweight were found to be *poorly related* with rainfall. Ledlie et al. 2018 showed no significant results of rainfall shock on wasting.

Drought year: despite that there were a couple of studies with overlapping years in which drought occurred, these studies were too heterogenous and different regarding malnutrition metrics, and details about drought exposure to be possible to compare.

4.4. Socio-economic factors

Main risk factors for malnutrition after drought exposure are listed below (table 3). Effect measures are provided when available. Risk factors were either investigated as effect modifiers, which show the stratified results for different categories of a variable in regression analyses, or risk factors were identified by separate analyses of prevalence.

Table 3. *Main socio-economic factors that showed significant impacts on the interplay between drought and malnutrition.* Note: infection disease is not included as risk factor because this was considered a mediator (indirect mechanism between drought and malnutrition).

Socio-economic variable	Impact	Key findings
Production of a variety of crops	Increased risk	• Pulses: producing pulses is associated with a **sign reduced HAZ** in drought circumstances (b=−2.081) (Bakhtsiyarava & Grace, 2021). • Meat: meat producing households had a (b=-0.66) **sign lower WHZ** (Bakhtsiyarava & Grace, 2021).
Pastoralists	Increased risk	• **Fluctuations in wasting were greater** among pastoralists during years of drought (25%) while the prevalence among agricultural populations seldom exceeded 15% (Chotard et al., 2010). • Relation between drought and food security showed a **stronger effect** in pastoralists (Mason et al., 2010).
Poor families	Increased risk	• Children from poor families (adjusted odds ratio; 1.3; 95% CI, 1.1-1.6)] **were at risk** for anemia compared to richer families (Gari et al., 2017).
Uneducated mothers	Increased risk	• Highest maternal education: children born to uneducated mothers, regardless of the family's wealth status, are **more susceptible to stunting**. Does not hold for fathers education (Dimitrova, 2021).
Rural areas	Increased risk	• Children living in rural areas with households working in the agricultural sector are **highly susceptible** to droughts: **>30% increase in stunting and wasting** after drought (Dimitrova, 2021). **No significant effects** for children in urban areas or for children whose parents are not engaged in the agricultural sector.
Poor road connectivity	Increased risk	• **Undernutrition prevalence increased** in areas with **limited** primary road networks and **decreased with better** road connectivity (Hirvonen et al., 2020).
High- and midlands	Variable risk	• **Higher prevalence of stunting and underweight** were found in the highlands and midlands compared to the lowlands (Hagos et al., 2014). • Chotard et al. (2010) **found no significant impact** was seen in highlands and all other regions on wasting.
Sex	Variable risk	• **No sign difference** between girls and boys (Dercon & Porter, 2014; Hirvonen et al., 2020; Salama et al., 2001). • However, drought experienced between age 0 and 1 showed **an increased risk** on stunting for boys, **no sign effects** for girls (Dimitrova, 2021). No difference regarding wasting. • Haileamlak (2003) showed that girls **were more prone to severe protein energy malnutrition** than boys, especially age <2 y.
SES	Variable risk	• Increases in SES associated with an **increase in wasting prevalence** (10.8% to 8.5%) (in Oromia, both agriculturalist and pastoralist). However, for agriculturalist: higher SES among agriculturalists is associated with a **decreased stunting prevalence** (Mason et al., 2010)
Children under 2-3 y	Variable risk	• Children **12-36 months** (born during the famine) (Dercon & Porter, 2014). • (Dimitrova, 2021) showed that drought are **most impactful for the first two years of life.** • Aged **< 36 months** (AOR; 2.0; 95% CI, 1.6-2.4) were **at risk for anemia** (Gari et al., 2017). • On the contrary, **no difference** between age was shown by Hirvonen et al. (2020) and Ledlie et al. (2018).

4.5. Interventions

Six papers described the effect of an intervention on malnutrition prevalence as their main topic (De Waal et al., 2006; Doocy et al., 2005; Kaluski et al., 2002; D. K. Mekonnen et al., 2022; Salama et al., 2001; Tesfaye, 2022). All interventions were specifically conducted within a drought context. Three studies were about food aid, one study about financial aid and two studies about agricultural interventions. Results from these papers are summarized in (table 4). Based on these six papers, Interventions are generally not effective in reducing malnutrition prevalence except irrigation interventions.

Table 4. *Overview of interventions.*

Intervention type	Results individual studies	Key findings
Food aid 	Kaluski et al. (2002) 2-3 kg per 3 months, launched by the Ethiopian Disaster Prevention and Preparedness Commission in 1998. The prevalence of malnutrition increased in 1999 due to persistent drought together with other hazard events. Mid 1999, more food aid was provided, known as general feeding program. But needs were still not met. Food provision was delayed, there were distribution problems. The food aid in 1999/2000 contained mainly grains and was 12.5 kg pp per month. Did not reach all areas in need. As a reaction, supplementary aid that was provided right after. However, it was not as effective, because in practice the supplementary aid was provided alone and not in conjunction with the general feeding program as intended. Consequence: ill children were left alone when parents were collecting food. Furthermore, early warning systems were not working optimally. Lack of coordination, harmonization and providing help on time. Food aid did not met the needs for macro and micro nutrients. In 1999: highest prevalence of malnutrition was found in food-surplus regions in Ethiopia.	• Higher prevalence of malnutrition after intervention suggests **ineffectiveness**. • Food security alone not the only factor responsible for malnutrition. • **Lack of** coordination, harmonization and providing help on time. • Food aid **did not met** the needs for macro and micro nutrients.
Food aid 	De Waal et al. (2006) 600.000 tons of food in Afar, Amhara, Oromia and Tigray. 13 million children were screened for their risk on malnutrition. Food aid had a small but sign positive association with child survival, even though underlying causal mechanisms of this association or the role of confounding factors could not be identified. While food aid was sign associated with better child survival, the association was only modest. To give an idea of the order of magnitude of the effect, the combined impact of socio-economic factors on malnutrition was higher than the effect of the intervention. Food aid should be administered together with good drinking sources and other efforts such as good livestock ownership to make livelihoods more comfortable and to be most effective. Effect on short term malnutrition could not be determined because it was not measured directly after food aid provision.	• Food aid had a **small but significant positive** association with **child survival**, but should be interpretated with **caution**.

Supplementary feeding program 	Salama et al. (2001) Defined as additional food provision by humanitarian organizations for people who need it. In times of this study there was a measles outbreak. 21.5% (95% CI, 7.4%-35.7%) of children were eligible for enrolment in supplementary feeding programs (WHZ<70%), only 4 children received it (12.1%). The humanitarian response was delayed and inadequate. Food aid only delivered at a few central places. The intention was to focus on food-related aid. However, coverage was low due to amongst other bad infrastructure and acceptance by communities. The provision of aid at centralized locations only resulted in a high attractiveness of vulnerable ill and malnourished people to those sites resulting in high transmissions of infection diseases. In the future, interventions should be provided at more locations.	• **Limited** children received intervention. • Help was **delayed** and **inadequate**.
microfinance intervention 	Doocy et al. (2005) Provided shortly after a drought event. This type of lending program includes access to capital, increased income, and women's empowerment. No sign overall difference in mean MUAC was found among children of the 3 intervention control groups (p=0.415, ANOVA). But, sign differences exist within the survey sites. The causality of participation in lending programs and increased nutritional status should be interpreted with caution as only 20% of the participants reported that the intervention met household needs. Furthermore, males and community controls were more likely to have received food aid 1.94 (95% CI: 1.05–3.66) and 2.08 (95% CI: 1.10–4.00) compared to women with their children. Lastly the intervention did not change the cooping behavior in any of the participants.	• **No strong evidence** that the intervention was effective.
Small scale irrigation 	Mekonnen et al. (2022) Irrigation (binary) defined as having used irrigation on at least one field during any season. Farmers were allowed to chose the type of irrigation that they preferred: manual and motor pumps, monitoring soil moisture detectors, drip kits, in situ water harvesting and more. Irrigation improves WHZ in Ethiopia by 0.87 SDs (normal weather conditions). Among Ethiopian households who reported having faced drought, women in irrigating households have higher Women's Dietary Diversity Score (WDDS) compared to women in non irrigating households.	• *Normal weather conditions*: Irrigation **improves** WHZ by 0.87 SDs. • *Drought conditions*: women in irrigating households have **higher** Women's Dietary Diversity Score (WDDS) compared to women in non irrigating households.
Crop diversification 	Tesfaye (2022) Defined by the number of crops grown per household and by the Shannon index. In drought shock conditions, crop diversification (Shannon index and nr) has a positive small non sign impact on child stunting and wasting (CI's overlap). In other words, children in areas that experience drought do not have less severe malnutrition conditions after the intervention.	• Drought **does not mitigate** the impact of crop diversification on malnutrition suggesting a neutral effectiveness.

4.6. Risk of bias assessment

Table 5 provides an overview of the ROB assessments. Most studies, 10 out of 17 (59%), had a high overall risk of bias (table 5 grey column). 6 studies (35%) had an overall low risk of bias (Dimitrova, 2021; Gari et al., 2017; Georgiadis et al., 2021; Hirvonen et al., 2020; Ledlie et al., 2018; Tesfaye, 2022) and 1 had some concerns (Salama et al., 2001). All studies were assessed with (probably) low risk of bias for the domains 'selection strategy' and 'selective reporting', meaning that generally the selection of participants was transparent and that populations were representative, and that all outcomes intended to measure were also reported in the results section. Full descriptions of assessments are provided in appendix F.

'Exposure data, 'confounding' and 'outcome data' were the domains with the most concerns about bias, as these categories were most represented by high risk of bias. These 3 domains therefore contribute most to the overall high risk of bias assessment for the 6 studies (35%). Examples when 'exposure data' was assessed with (probably) high risk of bias was when effect measures for drought were not provided, when national drought indicators where used while the study area was focused on local scale only (Gode district) or when drought was not recorded consistently in surveys. Examples when 'confounding' was assessed with (probably) high risk of bias was when there was nothing mentioned about confounding, when there was adjusted for only a minor collection of disturbing factors, or when there was controlled for household characteristics, but not for confounders that might disturbed the relation between exposure and outcome variables. Examples when 'outcome data' was assessed with (probably) high risk of bias was when height in cm was used and not height-for-age Z scores, when it was not mentioned how the outcome data was collected, when standard cut-off values were used for a few malnutrition metrics but not for all, when there was not referred to WHO or another high quality source, or when they relied on recall.

Furthermore, most studies explicitly reported that they did not have involvement of entities with financial interest in the study outcome. One study did not provide information about conflicts of interest. Almost all studies did not mention blinding strategies but provided other indirect information. Most studies provided some information about their measurement procedures and used reliable instruments for this.

Table 5. *Risk of bias assessment*.

	Selection strategy	Blinding	Exposure data	Confounding	Outcome data	Selective reporting	Conflict of interest	**Overall risk of bias**
M. Bakhtsiyarava								High risk of bias
S. Chotard								High risk of bias
S. Dercon								High risk of bias
A. Dimitrova								Low risk of bias
S. Doocy								High risk of bias
T. Gari								Low risk of bias
A. Georgiadis								Low risk of bias
A. Haileamlak								High risk of bias
K. Hirvonen								Low risk of bias
D. Kaluski								High risk of bias
N. Ledllie								Low risk of bias
J. Mason								High risk of bias
D. Mekonnen								High risk of bias
W. Tesfaye								Low risk of bias
A. de Waal								High risk of bias
S. Hagos								High risk of bias
P. Salama								Some concerns

Legend

	Low risk of bias		Probably high risk of bias		Not applicable
	Probably low risk of bias		High risk of bias		Unclear

5. Discussion

In this systematic review, it was attempted to investigate the impact of drought on malnutrition among children under five child by answering 3 sub questions about 1.) the physical impact of drought, 2.) socio-economic risk factors and 3.) the effectiveness of interventions implemented to decrease malnutrition specifically in a drought episode context. A total of 17 articles appeared eligible for answering these questions. Findings should be taken with caution as papers were heterogenous (example; a lot of different drought metrics reported by individual studies) and 10/17 studies were assessed with high risk bias, which means that there is a high risk that the study outcome is systemically deviating from the veracity. Nonetheless, this research has contributed by giving an overview of impacts, vulnerability factors and interventions using a coherent approach and specifically focusing on children under five in Ethiopia. Previous literature, mainly focused on all low income countries all together, mixing adults and children in study populations (Belesova et al., 2019; Das et al., 2020; Lieber et al., 2022). Therefore this thesis provides an in depth analyses including up to date evidence.

5.1. Discussion of main results

Impact on malnutrition

Overall, there was an impact of drought on malnutrition as a whole, but evidence was inconsistent, generally in line with (Belesova et al., 2019; Lieber et al., 2022). Also in line with results conducted in neighboring country Kenya (Bauer & Mburu, 2017). This inconsistency was to be expected as studies were included with a variety of malnutrition metrics and different durations and years of drought events spanning variable locations in Ethiopia. These factors can all impact the relation between drought and malnutrition (see conceptual framework).

Considering single malnutrition metrics, the majority of the papers that reported *stunting* metrics reported that drought was associated with an increased stunting prevalence. Also, one paper suggested diminished growth (5.3 cm) after drought. Positive significant associations regarding stunting was previously shown in for instance (Phalkey et al., 2015).

Other than stunting, papers that reported *wasting* metrics generally reported no significant association and in case there was significance, variable associations were shown. The lack of a significant positive association could be explained by the mismatch between disease onset and the timing or duration of exposure to drought that may have concealed the acute onset of wasting. Alternatively, the provision of food aid could have relieved detrimental effects of drought. Food aid was often mentioned to be administered, and it was unclear whether there was adjusted for this.

In line with wasting, impacts on *underweight* varied as well. This was not surprising as underweight is defined as low weight for age and can be a combination of both stunting and wasting appearances. To put this in perspective, (Lieber et al., 2022) (focus on whole SSA and also on adults) also found that in some papers underweight prevalence was significantly increased and in some papers it decreased. In the description of the study context of the paper that did not show a clear association of drought and malnutrition, it was described that food aid was provided during that study and has possibly decreased the impact.

Results suggested that *mortality* rates are increased after drought, suggesting that we should not underestimate the effect of drought because drought can make a difference between life and dead. It was unclear thought whether the impact on mortality was due to drought or other underlying chronic hazards such as high poverty and conflicts rates.

Socio-economic risk factors

Important significant socio-economic risk factors identified where: households producing a variety of crops, pastoralists, rural areas, roads with poor connectivity, poor families and uneducated mothers. What stands out is that children's vulnerability is dependent on household characteristics. Children living remotely are suggested at risk because of the risk factors poor access to roads and rural areas. This is logical since these

areas probably have lower health and education facilities. Generally all risk factors are largely in accordance with previous reviews (Abdulahi et al., 2017; EPHI, 2022; Lieber et al., 2022; Salvador et al., 2023; Stanke et al., 2013).

I will discuss a few noticeable findings. This study found that pastoralist are extra vulnerable, while in contrast Belesova et al. (2019) found that agriculturalists are more vulnerable. For both groups a plausible explanation can be suggested. On one hand, agriculturalists could be extra vulnerable due to the high reliance on water sources for crop production. On the other hand, pastoralist are often localized in areas that are more and more prone to desertification and pastoralist therefore migrate to areas with higher food security levels. On long term, these crowded areas loss their resilience due to increased water demand.

Another interesting finding was that SES was not a clear risk factor, while poor families was. This can have multiple reasons, one of them is that it had to do with differences in study characteristics such as the design, duration of drought and outcome used. Furthermore, sex showed variable results as well, sometimes girls were more at risk, sometimes boys. A reason why boys would be more at risk is because boys could be more in need of energy for growth during childhood and therefore shortages in food could be more detrimental. Girls on the other hand might physically be weaker in general.

Lastly, the production of a lot of crops was found to be a risk factor for drought, which sound counterintuitive at first side. Bakhtsiyarava & Grace et al. (2021) showed namely that in a context of poor rainfall, more diversity in farm production could worsen HAZ. Nonetheless, production of a diverse spectrum of food was suggested to be a risk factor was because caregivers that produce more different kinds of crops possibly have less time for breastfeeding and child care and this will have a negative impact on nutritional status of children. Also, it was suggested that farmers that produce larger variety of crops are simply affected more when they face drought, reducing the general food availability in the country (Bakhtsiyarava & Grace, 2021).

Interventions

Given that only a small number of inventions was identified, we cannot draw hard conclusions. Interventions were generally not effective, mainly due to inadequate and late provision of high quality food, and the clustering of vulnerable people at places were food aid was provided. This facilitated spread of infection disease. The inadequacy of sufficient food intake among children after intervention was also reported earlier (Mohammed et al., 2020). This provides a perspective on that theoretically the intentions for food aid are thought through but there are shortcomings in practice.

Noteworthy, the agricultural intervention irrigation optimalization showed as only intervention effective results regarding malnutrition prevalence. As >80% of Ethiopians are working in the agricultural sector (Meskele et al., 2023), it could be groundbreaking to implement optimal irrigation techniques throughout the country. Also, a small decrease in child mortality was reported, although results should be taken with caution (De Waal et al., 2006). This suggest that we should continue providing food aid in Ethiopia as it may make a difference between life and death.

5.2. Strengths and limitations

The strengths of the study were the substantial number of databases that were used for data selection and the high number of papers that were assessed for eligibility. This has probably minimized the overlooking of relevant papers. Furthermore, this thesis was conducted in a structured way making use of logbooks, clear subheadings and tables to summarize results. Additionally, few papers have investigated the impact of drought on child malnutrition in Ethiopia only. This was insightful as policy recommendations can be narrowed to an area with a relatively homogeneous culture and climate. Moreover, all sorts of drought and malnutrition metrics were considered and this study included up to date literature. This paper was assumed reliable, as there was strictly adhered to PRISMA guidelines and this ROB assessment made sense as reviews that incorporated similar individual studies for their ROB showed not very different ROB assessments (Belesova et al., 2019). Also, the ROB assessments provided argumentation for all assessments, which was not always the case in previous research (Ahmed et al., 2023).

Limitations of this thesis were that numerous studies had high ROB, were not always clear about the season or duration of drought exposure and it was not always clear if authors had taken this into account. This could have biased results. In addition, a DHS was consulted in multiple papers which is an example of secondary research in which surveys are designed for the general obtainment of population characteristics and are therefore initially not designed for answering the research question of this thesis. Moreover, English papers were considered only. Additionally, the heterogeneity of included studies makes it hard to give one single effect measure of drought on malnutrition and therefore one magnitude of impact could not be provided. Due to the limited time span of this thesis, a quality assessment could not be performed but it was expected that a risk of bias assessment already provided a good grasp on the level of reliability. Also, there were often gaps in the years of drought within individual studies making it undoable to provide longitudinal effect estimations.

General limitations regarding research about drought and malnutrition are the overall lack of research. This is mainly due to the lack funding and sufficiently developed monitoring systems (Ethiopian Public Health Institute, 2022). Papers that are available regarding this topic often 1.) rely on indirect drought proxies, 2.) lack descriptions of causal mechanisms, confounders and seasonal variance, 3.) lack experimental study designs as drought is a natural phenomena that occurs slowly over time without proper start and end point, 4.) lack control arms and 5.) rely on retrospective designs.

5.3. Policy recommendations

Holistic approach

The impact of drought on malnutrition is complex and therefore there should be opted for implementation of interventions that are both preventative but mitigative/adaptative both combining short and long term interventions. Different types of aid is still needed as vulnerability factors range from lack of education, to the inability to pay for food and the type of livelihood.

Underlying chronic national and regional problems should be diminished to increase resilience. Suggestions are the improvement of health care facilities (to reduce infections disease and measles outbreaks), education, sanitation, political instability.

Inclusion of the most vulnerable

Special attention should be paid to the identification and involvement of vulnerable groups in food interventions. Interventions should improve in the accessibility for people. For instance, families that are living more remotely should be involved by increasing the connectivity and condition of infrastructure for people to have the opportunity to reach the food aid. Furthermore, conversations should be started with (remote) communities to learn form their preferences.

Additionally, it is recommended that the number of food provision points increase to avoid clustering of people that are vulnerable for infections disease. Infection disease is namely a mediator between drought and malnutrition the current situations therefore creates an opposite effect (increasing malnutrition prevalence). Increasing the number of food aid spots is expected to have another benefit. Parents might leave their children less time alone when food can be collected from spots more nearby. This issue mentioned by previous research (appendix D) could than be avoided.

Timely and adequate food provision

Food aid seemed to be provided, but complaints were that food was received with a delay or not received at all. In case that families did receive food aid, it was often not the right quantity and quality. Worrisome, evidence from the Ethiopian Public Health Institute (2022) showed that there is still not enough high quality food and this stresses the need for more funding. Another recommendation would be to increase the provision more diverse food by professional educated staff (Salvador et al., 2023).

Enhance resilience

Recovery from drought takes years (WFP, 2023) and multiple papers showed that years later, regions were still affected by it dealing with a high prevalence (appendix D). Efforts to prevent health damage due to drought should be prioritized. The implementation of improved irrigation techniques is a good example as this prevents crops from being damaged. This intervention should be upscaled throughout the country.

5.4. Future research

Main suggestions are to monitor drought impacts more frequently as there was lack of high quality studies in general. More studies should be conducted about droughts of similar characteristics as this could be insightful for future systematic reviews that aim to quantify the impact by a single effect measure. This systematic review could not provide a magnitude of the overall impact but only significance levels and directions. Future studies should pay attention to careful matching of exposure to drought and onset of malnutrition to avoid that short term effects could not be identified when long term exposure were used and the other way around. Attention should also be paid to carefully documenting and correcting for confounding as this was not always clear. For instance, food aid was sometimes described to be present but there was not always corrected for this. Moreover, studies are needed about the impact of drought in combination with ecological compound hazards, as there was no research available about Ethiopia. The impact on micro nutrient deficiency was also limited but could be insightful to investigate as drought likely impacts the nutrient density in crops. Furthermore, future research should focus on identifying what type of irrigation, for instance manual and motor pumps, monitoring soil moisture detectors, drip kits or in situ water harvesting is the most effective and in which area. Also, the impact of drought-resilient crops can be explored as this is a promising intervention in other research areas (Erekalo & Yadda, 2023). Building on knowledge from this thesis, results can potentially be a good starting point for conducting future spatial analyses. Knowledge about vulnerability can for instance be used to investigate risk areas where vulnerable people cluster.

6. Conclusion

The current systematic literature review provides an overview of the impact of drought on malnutrition among children under five years old. In total, three sub questions have been answered using 17 eligible papers. Results of this study should be considered with caution due to the heterogeneity of included studies, the lack of control arms, and the low number of studies available for sub questions.

Nonetheless, this thesis suggests that generally there is an impact drought on malnutrition as more than half of the papers reported this. A significant positive association is mainly seen, but also varied results and results are dependent on the context and the vulnerability of the study population. Main socio-economic risk factors are identified and children's vulnerably seems to be dependent on household characteristics. Six studies were identified that investigated the effectiveness of interventions and ranged from food and financial aid to agricultural interventions. Interventions are still not effective except irrigation that appeared effective in reducing malnutrition prevalence. Minor evidence from one paper suggested that food aid diminishes child mortality.

Recommendations are to approach this malnutrition problem holistically and the resilience in general should be improved. Underlying chronic hazards should be alleviated, as it was suggested that these hazards possibly explain (a part of) the impact of drought on malnutrition. Also, vulnerable populations should be the core focus in interventions. Suggestions are to optimize the infrastructure and provide high quality and timely food. Avoidance of cross-contamination among vulnerable groups during food collection is also suggested. Moreover, there should be invested in research and implementation of irrigation techniques on national level as results of this thesis were promising.

Lastly, individual studies showed that still >40% of children under five in Ethiopia is malnourished (Gari et al 2017; Tesfaye et al., 2022) and that drought events on average caused millions of victims. High quality research and interventions should thus be prioritized due to the urgency and complexity of the problem.

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Appendix A. Search strategy

Example of full search strategy used in PubMed for Ethiopian studies.

Search	Query
#10 filter	(#1 AND #2 AND #5 AND #6 AND #7) OR (#1 AND #3 AND #5 AND #6 AND #7) OR (#1 AND #5 AND #6 AND #7) OR (#1 AND #4 AND #5 AND #6 AND #7) NOT "meta-analysis"[publication type] NOT "systematic review"[Publication Type] NOT "review"[Publication Type] Filters: English, from 2000/1/1 - 2024/4/22, humans
#9	(#1 AND #2 AND #5 AND #6 AND #7) OR (#1 AND #3 AND #5 AND #6 AND #7) OR (#1 AND #5 AND #6 AND #7) OR (#1 AND #4 AND #5 AND #6 AND #7) NOT "meta-analysis"[publication type] NOT "systematic review"[Publication Type] NOT "review"[Publication Type]
#8	(#1 AND #2 AND #5 AND #6 AND #7) OR (#1 AND #3 AND #5 AND #6 AND #7) OR (#1 AND #5 AND #6 AND #7) OR (#1 AND #4 AND #5 AND #6 AND #7)
#7	Ethiopia[tiab] OR Ethiopian*
#6	"Child"[mesh] OR "infant"[Mesh] OR "child, preschool"[mesh] OR "newborn"[tiab] OR "Preschool"[tiab] OR "children"[tiab] OR "infant*"[tiab] OR "child*"[tiab] OR "girl"[tiab] OR "boy"[tiab] OR "girls"[tiab] OR "boys"[tiab] OR "youth*"[tiab] OR "pediatr*"[tiab] OR "paediatr*"[tiab] OR "under five"[tiab] OR "under 5"[tiab] OR "under-5"[tiab] OR "perinatal"[tiab]
#5	"malnutrition"[Mesh] OR "nutrition disorders"[Mesh] OR "food insecurity"[Mesh] OR "hunger"[Mesh] OR "nutritional status"[mesh] OR "malnutrition"[tiab] OR "nutrition disorder*"[tiab] OR "food insecurity"[tiab] OR "hunger"[tiab] OR "nutritional status"[tiab] OR "Nutritional Deficien*"[tiab] OR "undernutrition"[tiab] OR "undernourish*"[tiab] OR "malnourish*"[tiab] OR "under-feeding"[tiab] OR "stunting"[tiab] OR "low birth-weight*"[tiab] OR "poor nutrition"[tiab] OR "wast*"[tiab] OR "under-weight*"[tiab] OR "nutrient deficien*"[tiab] OR "protein deficien*"[tiab] OR "calorie deficien*"[tiab] OR "micronutrient deficien*"[tiab] OR "hunger"[tiab] OR "marasmus"[tiab] OR "kwashiorkor"[tiab] OR "protein energy malnutrition"[tiab] OR "protein loss"[tiab] OR "nutrient loss*"[tiab] OR "protein intake"[tiab] OR "nutrient intake"[tiab] OR "micronutrient intake"[tiab] OR "protein-energy malnutrition"[tiab] OR "caloric restriction"[tiab] OR "body weight*"[tiab] OR "food deprivation"[tiab] OR "energy Intake"[tiab] OR "deficiency disease*"[tiab] OR "growth disorder*"[tiab] OR "nutritional status"[tiab] OR "thinness"[tiab] OR "energy Intake"[tiab] OR "nutrition assessment"[tiab] OR "nutrition surveys"[tiab] OR "Diet"[tiab] OR "iron-deficiency"[tiab] OR "anemia"[tiab] OR "Vitamin A deficiency"[tiab] OR "folic acid deficiency"[tiab] OR "deficiency diseases"[tiab] OR "protein deficiency"[tiab] OR "obesity"[tiab] OR "metabolic Diseases"[tiab] OR "metabolic syndrome"[tiab] OR "nutrition assessment"[tiab] OR "enteral Nutrition"[tiab] OR "parenteral nutrition solutions"[tiab] OR "child nutrition disorders"[tiab] OR "nutrition surveys"[tiab] OR "Infant nutrition disorder*"[tiab] OR "health"[tiab] OR "emergencies"[tiab] OR "nutrition"[tiab] OR "nutrition outcomes"[tiab] OR "growth"[tiab] OR "Health vulnerability"[tiab] OR "Food related behavior*"[tiab] OR "food insecurit*"[tiab] OR "famine"OR "weight for height"[tiab] OR "weight for age"[tiab]
#4	"Nutritional Support"[Mesh] OR "Nutritional Support"[tiab] OR "dietary changes"[tiab] OR "supplementation"[tiab] OR (("Education* program*"[tiab] OR "Intervention*"[tiab] OR "address*"[tiab] OR "provision" [tiab] OR "mitigate*"[tiab] OR "adapt*"[tiab] OR "solution"[tiab] OR "program"[tiab] OR "implement*"[tiab] OR "risk lowering"[tiab] OR "risk reduction"[tiab] OR "assistance"[tiab] OR "challenge"[tiab] OR "target*"[tiab] OR "strateg*"[tiab] OR "protect"[tiab] OR "prevention"[tiab] OR "threat*"[tiab] OR "Priorit*"[tiab] OR "response"[tiab] OR "diet*"[tiab] OR "distribution"[tiab] OR "voucher*"[tiab] OR "aid"[tiab] OR "action"[tiab] OR "programmes"[tiab]) AND ("nutr*"[tiab] OR "food"[tiab] OR "malnutrition"[tiab] OR "feed"[tiab]))
#3	"Vulnerable population*"[Mesh] OR "sociological factor*"[Mesh] OR "Vulnerable

	population*"[tiab] OR "sociological factor*"[tiab] OR ("Factor*"[tiab] AND "Sociological"[tiab]) OR "Sociological Phenomena*"[tiab] OR (Phenomena*[tiab] AND Sociological [tiab]) OR "Social Characteristics"[tiab] OR ("Characteristics"[tiab] and "Social"[tiab]) OR "Social Trait*"[tiab] OR ("Social"[tiab] and "trait"[tiab]) OR "Sociological Characteristic*"[tiab] OR ("Characteristic"[tiab] AND "Sociological"[tiab]) OR "Social Attributes"[tiab] OR ("Attribute"[tiab] AND "Social"[tiab]) Or "vulnerable"[tiab]
#2	"Wildfire*"[Mesh] OR "Extreme heat*"[Mesh] OR "hot temperature*"[Mesh] OR "air pollution"[Mesh] OR "Particulate Matter"[Mesh] OR "traffic-related pollution"[Mesh] OR "Wild fire*"[tiab] OR "Wildfire*"[tiab] OR "bushfire*"[tiab] OR "bush fire*"[tiab] OR "forest fire*"[tiab] OR "wildland fire*"[tiab] OR "brushfire*"[tiab] OR "brush fire*"[tiab] OR "rural fire*"[tiab] OR "grassfire*"[tiab] OR "grass fire*"[tiab] OR "vegetation fire*"[tiab] OR "landscape fire*"[tiab] OR ("fire*"[tiab] AND "wild"[tiab]) OR "extreme weather"[tiab] OR "heat"[tiab] OR "heat wave"[tiab] OR "extreme heat"[tiab] OR "high temperature"[tiab] OR "temperature rise*"[tiab] OR "temperature increase*"[tiab] OR "temperature elevation"[tiab] OR ("Warm*"[tiab] OR "hot" [tiab] OR elevat*[tiab] AND "temperature*"[tiab]) OR "extreme hot weather" [tiab] OR ("heat"[tiab] AND "extreme"[tiab]) OR "air pollution"[tiab] OR "particulate matter"[tiab] OR "air quality"[tiab] OR ("air"[tiab] AND "quality"[tiab] OR "pollution"[tiab]) OR "ultra fine fiber*"[tiab] OR ("fibers"[tiab] AND "ultrafine"[tiab]) OR "Airborne Particulate Matter"[tiab] OR ("Particulate Matter"[tiab] AND "Airborne"[tiab]) OR "Particulate Air Pollutants"[tiab] OR "Ambient Particulate Matter"[tiab] OR ("Particulate Matter"[tiab] AND "Ambient"[tiab]) OR "Ultrafine Particulate Matter"[tiab] OR "Ultrafine Particle*"[tiab] OR ("Particle*"[tiab] AND "Ultrafine"[tiab]) OR "Hazard"[tiab] OR "simultaneous*"[tiab] OR "concur*"[tiab] OR "successi*"[tiab] OR "combination*"[tiab] OR "amplification"[tiab] OR "co-occur*"[tiab] OR "compound*"[tiab] OR "risk exposure"[tiab] OR "impact"[tiab] OR "natural disaster*"[tiab]
#1	("Drought*"[Mesh] OR "climate change"[Mesh] OR "drought*"[tiab] OR (("Climat*"[tiab] OR "weather"[tiab]) AND ("chang*"[tiab] OR "variab*"[tiab] OR "extreme*"[tiab])) OR "global warming"[tiab] OR "arid*"[tiab] OR "dessicat*"[tiab] OR (("Drought*"[tiab] OR "Arid*"[tiab] OR "Dry"[tiab] OR "rainless"[tiab] OR "rain-less"[tiab]) AND ("condition*"[tiab] OR "weather"[tiab] OR "period"[tiab] OR "season"[tiab] OR "Spell*"[tiab])) OR (("water"[tiab] OR "precipitation"[tiab] OR "rain"[tiab]) AND ("lack"[tiab] OR "low"[tiab] OR "change"[tiab] OR "depriv*"[tiab] OR "stress*"[tiab])) OR "water-related disaster"[tiab] OR "extreme event"[tiab] OR "extreme weather"[tiab] OR "desert climate*"[tiab] OR "water deficit"[tiab] OR "water-energy-food nexus"[tiab] OR "extreme weather events"[tiab] OR "Changing weather"[tiab] OR "Climate variability"[tiab] OR "Shock"[tiab])

Appendix B. Reasons for exclusion at the stage of the full text review

Reason for exclusion	Studies (author, year)	N
Link between drought and malnutrition is missing.	(Abate et al., 2019) (Abdulahi et al., 2024) (Abejew et al., 2014) (Ahmed et al., 2016) (Akresh et al., 2022) (Alemayehu et al., 2020) (Amele et al., 2019) (Anyanwu et al., 2022) (Ararsa et al., 2023) (Argaw et al., 2019) (Basnet et al., 2020) (Batiro et al., 2017) (Baye, 2019) (Baye et al., 2022) (Bayih et al., 2022) (Bekele et al., 2021) (Belachew et al., 2007) (Berelie etl al., 2019) (Berhanu et al., 2018) (Bidira et al., 2021) (Cintron et al., 2016) (Daoud et al., 2017) (Demilew et al., 2017) (Deribew et al., 2016) (Etzel et al., 2015) (Fagbamigbe et al., 2020) (Fink et al., 2014) (Gasjaw et al., 2024) (Gebreegziabher et al., 2019) (Girum et al., 2017) (Girum et al., 2018) (Gizaw et al., 2018) (Hadley et al., 2016) (Han et al., 2021) (Ibrahim et al., 2023) (Jebero et al., 2023) (Kabthymer et al., 2020) (Kassa et al., 2022) (Kebede et al., 2021) (Khalid et al., 2019) (Kitila et al., 2021) (Lamaro et al., 2023) (Larsen et al., 2019) (medhanyie et al., 2018) (Minuta et al., 2023) (Montt et al., 2020) (Mulugeta et al., 2010) (Ruducha et al., 2017) (Takele et al., 2020) (Teferi et al., 2010) (Tegegne et al., 2021) (Tesfay et al., 2024) (Tesfaye et al., 2018) (Turk et al., 2022) (Wagnew et al., 2018) (Wake et al., 2022) (Wasihun et al., 2018) (Woldeamanuel et al., 2019) (Workie et al., 2021) (Black et al., 2008) (Hailemiriam., 2022) (Gelu et al., 2018) (Kamangira et al., 2023) (Tafase et al., 2012)	65
Focus on children under five years old is missing.	(Abebe et al., 2017) (Adeoya et al., 2023) (Bahru et al., 2019) (Birhanu et al., 2021) (Chekol et al., 2024) (cherinet et al., 2000) (Cooper et al., 2019) (Gebre et al., 2021) (Gilligan et al., 2007) (Girma et al., 2023) (jones et al., 2020) (Kok et al., 2020) (Lumborg et al., 2021) (MacFarlane et al., 2019) (Megersa et al., 2014) (Morrow et al., 2017) (Opoku et al., 2021) (Presler-Marshall et al., 2022) (Rawat et al., 2022) (Smith et al., 2022) (Wake et al., 2023) (Sohnesen et al., 2019) (Dechassa Lemessa et al., 2001) (Abate et al., 2016)	24
Animal study.	(Abu et al., 2018)	1
Full text not available.	(Baguma, 2017) (de Sherbinin et al, 2011) (Mayige et al., 2022)	3
Ethiopia is not researched separately.	(Amadu et al., 2021) (Anttila-Hughes et al., 2021) (Baker et al., 2020) (Choudhury et al., 2019) (Flückiger et al., 2022) (Le et al., 2021) (Haile et al., 2018) (Grace et al., 2015)	8
About infection disease.	(Alemayehu et al., 2020) (Alemayehu et al 2020) (Azage et al., 2017) (Baye et al., 2021) (Kwami et al., 2019) (mengistie et al., 2022)	6
Explicit drought event is not mentioned or quantified, the study area is 'just' drought prone, or about seasonal drought only.	(Abitew et al., 2020) (Ahmed et al., 2021) (Belayneh et al., 2021) (Belayneh et al., 2021) (Belete et al., 2018) (Beyene et al., 2020) (Bosha et al., 2019) (Brouwer et al., 2023) (Egata et al., 2013) (Fentaw et al., 2023) (Gebremedhin et al., 2021) (Girard et al., 2021) (Haidar et al., 2009) (Kabalo et al., 2022) (Kasaye et al., 2019) (Koch et al., 2021) (Lee et al., 2022) (Lindtjorn et al., 2002) (Miller., 2017) (Moisisa et al., 2021) (Omer et al., 2022) (Randell et al., 2021) (Randell et al., 2020) (Sahiledengle et al., 2024) (Tadele et al., 2022) (Tamene et al., 2023) (Tarekegn et al., 2022) (Wachamo et al., 2019) (Asfaw et al., 2015) (Kamangira et al., 2023) (Njatang et al., 2023)	31
About interventions in general, not in the context of drought and malnutrition.	(Abreha et al., 2021) (Adimasu et al., 2020) (Asfaha et al., 2018) (Bidira et al., 2022) (Bire et al., 2023) (Bitew et al., 2021) (Busse et al., 2017) (Chea et al., 2018) (li et al., 2020) (Malako et al., 2019) (Mekonnen et al., 2022) (Miller et al., 2014) (Misganaw et al., 2022) (muleta et al., 2021) (Roba et al., 2024) (Schoeman et al., 2010) (Teshome et al., 2009) (Torres et al., 2021) (Wondim et al., 2020) (Yigrem et al., 2015) (Abiyu et al., 2020) (Argaw et al., 2018) (Kang et al., 2017) (Fenn et al., 2012) (Teshome et al., 2022) (Kim et al., 2016) (Kang et al., 2016) (Kang et al., 2016) (Mulualem et al., 2016) (Bildira et al., 2022) (Kim et al., 2019) (Samuel et al., 2018) (Han et al., 2021) (Akalu et al.,	37

	2010) (Mekonnen et al., 2022) (Woldie et al., 2019) (Degefa et al., 2021)	
Wrong study area at all.	(Alemauehu et al., 2020) (Bornstein et al., 2015) (Elmallakh et al., 2023) (Hartinger et al., 2020) (hassan et al., 2023) (Ickes et al., 2021) (Jiang et al., 2023) (Kalhoff et al., 2023) (Macheka et al., 2022) (Mwaniki et al., 2013) (Silachew et al., 2020) (Worku., 2003) (Dilon et al., 2015) (Adeyinka Abideen., 2023)	14
Wrong study design (scenario analysis, meta-analysis or Review).	(Alemayehu et al., 2015) (Bazzano et al., 2017) (Bernstein, 2011) (Delbiso et al., 2017) (Hanna et al., 2016) (Keats et al., 2020) (Lakhoo et al., 2024) (Verdin et al., 2021) (Napa, 2016) (lesk et al., 2022) (Grace et al., 2015) (Trasic et al., 2020)	12
Child malnutrition metric according to inclusion criteria is missing (for instance agricultural productivity or fluorosis is used).	(Kasis et al., 2001) (Malde et al., 2003) (Malde et al., 2004) (Randell et al., 2016) (Coffel et al., 2019) (Irenso et al., 2022)	6
Vague drought metric, wrong drought metric or (e.g. “land scape fire”) or drought combined with several other non ecological hazards.	(Asfaw et al., 2018) (Chikako et al., 2021) (Karra et al., 2017) (Kuse et al., 2022) (Li et al., 2021) (Tesfay et al., 2019) (Usman et al., 2019) (Usman et al., 2021)	8
Wrong or vague compounding hazards or not analyzed together with drought.	(Alemayehu et al., 2020) (Andriano et al., 2023) (Bradshaw et al., 2019) (Han et al., 2021) (Joon et al., 2016) (Kleimann et al., 2022) (Li et al., 2021)	7
Duplicate.	(Njatang et al., 2023)	1
		Total : 223

Appendix C. Full description of inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Literature type	
• Peer-reviewed primary and secondary papers. • Both quantitative and qualitative metrics.	• No full text available. • Modeling papers, opinion articles, editorials, scenario analyses.
Population	
• Children <5 y/o or mother-child pairs or child-household relations living in Ethiopia.	• Animal studies.
Study area	
• Ethiopia.	• Other countries than Ethiopia.
Year of publication	
• 2000–2024 ensuring up to date high quality data. •	• Before year 2000.
Exposure-outcome link	
• The outcome should be investigated in relation to an explicitly mentioned drought event, drought shock or drought famine.	• Studies that are conducted in drought prone areas in general, meaning that drought event has not been explicitly mentioned, or only seasonal or mean temperature or precipitation values are given. In other words, weather and climate change in general rather than drought.
• The impact of previous or current drought on malnutrition should explicitly be described. Drought as defined by the primary or secondary article, mostly temp, precipitation deviations, or deviating standardized normalized difference vegetation index (NDVI), evapotranspiration, SPEI…	• Meaning of drought that is unrelated to climate. • Drought described by access to water, type of water source, improved water quality, distance to water etc. • Heat waves < 1 week duration. Heat waves lasts a week mostly and a drought event on the other hand months or years (Mishra & Singh, 2010). • Papers that combine drought with hazards (as the main study topic, not background/study context descriptions) other than ecological ones that could disturb the association. • Vague compounding hazards or not analyzed together with drought.
Outcome	
• Malnutrition defined by anthropometric measures such as nutritional status such as undernutrition, stunting, BMI, wasting, height, blood levels, mortality, birth weight, micronutrient deficiency, MUAC etc.	• Anemia diagnosed by other reasons than malnutrition (e.g. autoimmune disease), sepsis, malnutrition due to infection disease (schistosomiasis helminths), Trachoma, HIV/AIDS, vaccination, WASH, sanitation, kidney/urinary tract disease, menstruation, gene expression, food production, breeding, water quality, smoking, toxins in water, shock not related to malnutrition, interventions not focused on malnutrition,

	scabies, intensive care, emergencies in general, child feces only, waste dump, breastfeeding only, physical activity, mortality (without proper link to malnutrition). • Diarrhea as in 90% this is caused by infection disease and this thesis is not focused on infection disease. WASH as this is focused on reducing the spread of infections diseases. • Malnutrition defined by undernourishment, food security, dietary diversity or food intake.
Additional inclusion criteria	
• Papers that examine the effect of the ecological compound hazards heat waves, wild fires, or air pollution and should be investigated in relation to drought on malnutrition. • Studies that consider risk factors by incorporating stratified results specifically investigated risk factors or vulnerability factors in the context of drought and child malnutrition. • Papers that examine the effectiveness of interventions in the context of drought. The outcome should be malnutrition prevalence.	

Appendix D. Overview study characteristics.

First author(s) and year of publication	Geographical location	Type and age of sample	N	Data source	Study context and compound hazards	Event characteristics	Research objective	Drought exposure (or exposure to other variable in drought context)	Outcome(s)	Study design	Data collection period	Key results
Bakhtsiyarava et al., 2021	Ethiopia (Amhara, Oromia, Tigray, SNNPR).	Households including children under 59 months.	Children: 6214 (y 2011), 890 (y 2013), 1195 (y 2015), 201 (all years). 4000 households.	ESS Survey and meteorological data from CHIRPS. Survey data overlapped with meteorological drought in 2015-2016. Secondary data.	Rural and urban households. Loss of 1 million livestock, 10 million people affected by drought. High population density.	Drought in 2015-2016 caused delayed rain season and delayed rainfall in Central and North-Eastern Ethiopia. Drought overlapped with two main rain seasons. Loss of 50 - 90% crop production.	To measure the relationship between agricultural diversity and productivity and child malnutrition during sub optimal rainfall conditions.	-Suboptimal conditions: rainfall anomalies of more than−2SD below the long-term (1981–2016) average. Association between agricultural production diversity and composition, and outcome investigated when modified by exposure to suboptimal rainfall.	HAZ & WHZ < -2SD, moderate malnutrition.	Retrospective cohort study, use of longitudinal data. No control, but participants in areas with suboptimal rainfall exposure are compared to participants in areas with sufficient rainfall. Children serve as their own control due to the longitudinal design.	2011, 2013, 2015 (2015 relevant only)	At average farm production diversity, children from areas that received less than normal rainfall have sign lower HAZ (−0.124, P<0.05). Increase in farm production diversity reduces HAZ, but no sign impact on acute measures WHZ (0.018, P>0.05). It seems a good strategy to improve production diversity to reduce malnutrition. In a context of poor rainfall, more diversity in farm production can worsen HAZ.
Chotard et al., 2010	Ethiopia (Afar, Somali and Amhara, Oromia, SNNPR, Tigray) and Eritrea, Kenya, Somalia, Southern Sudan, Uganda.	Children 0 to 5 years or < 110 cm in height.	897 surveys, children not specified.	Survey data: DHS 2005 and multiple indicator cluster survey (MICS) for comparison. Secondary data.	Semi-arid and arid regions, vulnerable areas, separate analysis for pastoralists (low land), agriculturalists (high land), mixed, urban and migrants. 2000 and 2005-2006 are known for conflicts.	No details.	To investigate fluctuations in the prevalence of wasting due to seasonal variability of drought and variability by livelihood.	-Difference in crop production index. -Drought quantified on national level (binary, 1 = drought reported, 0 = drought specifically not reported or missing).	GAM (weight-for-height +edema)< −2 SD, WHZ <-2SD & HAZ<-2SD,	Cross-sectional, repeated for different years. No control, but adjusted for typical fluctuations by livelihood, season and year.	2000-2006	Years of drought (2000 and 2005–06) were associated with an increase in wasting. 8.7 percent point increase in wasting between 2000 and 2004 (reference, no drought year) adjusted for country year and season. 6.9 percent points for 2006 compared to 2004 adjusted for livelihood and season. On average 5% increase in wasting during seasonal fluctuations. Drought is positively associated with wasting in Afar and Somali, namely 2.159 percentage points higher for drought affected areas than no drought affected areas but not sign. Idem dito for Ethiopia all regions, 0.064 percent points, but not sign. Per livelihood: fluctuations in wasting were greater among pastoralists during years of drought, with prevalence rising to 25% or higher; prevalence among agricultural populations seldom exceeded 15%.
Dercon et al., 2014	18 villages in Ethiopia	Young adults 17–27 years with their children 12-36 months.	550 children	Survey data: 6th round of ERHS about the impact of the famine in 1989. Rainfall data: Ethiopian Meteorological Agency and the FAO, and NCDC GHCN database. Data used on the nearest rainfall station to the village which has no missing data for the relevant period. Primary and secondary data.	Europe and US donated aid (but delayed.) One of the worst famines in Ethiopia. Numerous hazards, military offensives, aerial bombardment of markets, damage to livestock and crops, tight controls on movements of migrants and traders, civil war. Normal conditions 'eventually' after end of drought.	1984 was extremely dry compared to previous 38 years (1961–1999). The main rain season started early, but dried up quickly resulting in a short rain season. Rainfall deficits >94%. Tigray, Eritrea, and Wollo. bearded most harm of drought.	To investigate whether experiences of famine in 1984-1985 in utero or at an age of 12-36 months had an impacts on child growth.	-Drought shock: rain shortfall in 1984–1985 compared to the ten-year mean. Positive value = deficit. -Drought shock (binary 1/0) reported by households as substantial loss of harvest in the last 20 years with the worst impact experienced in 1984.	-BMI -Height (cm). The height of young adults aged 19–22 years. Outcome 20 years after drought exposure.	Longitudinal quasi experimental (natural events causes selection). Retrospective. with control (unaffected people, vs affected people)	2004 mainly.	5.3 cm shorter in height compared to peers that were not affected by drought when they were 12-36 months of age. There was no sign impact of shock on other age groups. No sign results of children in utero and the impact on their height later in life. The coefficient is negative, but non sign. Regressions on BMI were not sign.
Dimitrova et al., 2021	90 low- and middle-income countries, including Ethiopia.	Women 15-49 years and their children under 5 years.	21.551 children	Survey data: DHS combined with geo referenced climate data (monthly precipitation and evapotran spiration) from CRU. Secondary data.	More croppers than agro-pastoralists represented.	Not specified, drought experienced during infancy.	Investigating inequalities and vulnerable groups regarding drought-induced undernutrition.	-Drought experienced during infancy (1/0). -SPEI: drought index (intensity scale) that combines heat stress and rainfall shortages. Negative values indicate drought conditions, positive indicate wet conditions. Values between 0.5 and −0.5 are considered near normal. Dry conditions are categorized into mild (−1 < SPEI < −0.5), moderate (−1.5 < SPEI ≤ −1), severe (−2 < SPEI ≤ −1.5), and extreme (SPEI ≤ −2). Wet conditions are categorized into mild (0.5 < SPEI ≤ 1), moderate (1 < SPEI ≤ 1.5) severe (1.5 < SPEI ≤ 2), and extreme (SPEI > 2).	HAZ & WHZ < -2SD and as binary(1/0). Wasting was measured during the last season belg & mere/kiremt. Stunting measured over life time due to its chronic onset.	Repeated cross-sectional surveys. No control.	2005, 2011, 2016	Strong association between drought exposure in early life and childhood undernutrition in Ethiopia, both for croppers and agro-pastoralists. Drought experienced in infancy increases the share of stunted children aged 0–5 by 3 % points (1% significance level), other variables held constant. At age 2 and above, the prevalence of stunting is still 4 % points higher when exposed to a drought in infancy. No sign association is found between exposure to a drought at age 2 and above and the risk of stunting. Results of SPEI 12 months (changes on yearly basis): Dry conditions during belg and extremely dry and wet conditions during bega also seem to increase the risk of child stunting, however, the large confidence intervals suggest imprecise estimates.
Doocy et al., 2005	Ethiopia (Sodo in Wolayita Zone in SNNPR and Adama the East Shewa Zone of the Oromia)	Female clients and their children age 6 - 59 months	819 households (614 Sodo, 205 Adamda). 608 children.	Survey data containing questionnaire-based interview results. Primary data.	Two rural sites in Ethiopia.	A severe drought in 2002/2003. Soda was the most drought-affected compared to Adama.	Investigating the outcomes of a microfinance program and the coping capacity in a drought context.	Exposure to the WISDOM intervention in drought context, 2002/2003. Measured in Months of participation and lending rounds.	-MUAC <11.0 cm severely malnourished, <12.5 > 11.0 cm moderately malnourished.	Cross-sectional design with 3 comparison groups (female WISDOM clients, similar non WISDOM clients and community controls). Control: participants who did not receive intervention in drought context.	May 2003	Mean MUAC for children was 14.3 cm. 5.8% were severely wasted. 10.2% of children were moderately wasted. No sign overall difference in mean MUAC was found among children of the 3 groups (p=0.415, ANOVA). But, differences exist within the survey sites.

Abbreviations: CHIRPS, climate hazards group InfraRed precipitation with station; ESS, the Ethiopia socioeconomic survey; GAM, global acute malnutrition; WHZ, weigh-for-height Z score; HAZ, height-for-age Z score; WAZ, weight-for-age Z score; ERHS, Ethiopian rural household survey; FAO, food and agricultural organization of the United Nations; NCDC, national climactic data center; GHCN, global historical climatology network; DHS, demographic health surveys; CRU, climatic research unit; SNNP, southern nations, nationalities, and peoples' Region; SD, standard deviation; SPEI, standardized precipitation-evapotranspiration index. Note: < 2SD means <2SD Child Growth Standards median; MUAC, mid-upper arm circumference.

Gari et al., 2017	Ethiopia (Adami Tullu district in Oromia).	Children 6 - 59 months.	About 3000. 2984 children in 2014, 3128 in 2015.	Survey data, as part of a field trial (PACTR201411000882128) that was about the combined use of long-lasting insecticidal nets and indoor residual spray for malaria prevention. Secondary data.	In 2014, the population of the district was about 173,000 people (12% children under 5). Livelihood: mixed agropastoralism, but most agriculture only. Communities received food aid and children with acute malnutrition were screened and treated. Malaria is common here. Participants in all villages were enrolled to malaria prevention trials.	Repeated droughts and food shortage throughout history. Severe drought triggered by El Niño in 2015 and early 2016. Annual rainfall was 673 mm in 2011, 909 mm in 2012, 745 mm in 2013, 673 mm in 2014 and decreased to 471 mm in 2015. The average maximum temperature was 27 °C in 2014, and 29 °C in 2015.	To investigate the prevalence of anemia, and to determine the risk factors of anemia.	This study took place during a period when there was 60% less rain.	-Anemia: children with hemoglobin <11 g/dl. -WHZ, HAZ, WAZ <-2 Z-scores.	Repeated cross-sectional with the same population. The study uses data from an RCT. No control: there are people without anemia, but not without exposure to drought.	2014, 2015	The prevalence of anemia was 28.2% (95% CI: 26.6-29.8) in 2014 and increased to 36.8% (95% CI, 35.1-38.5) in 2015 (P<0.001). The prevalence of HAZ <-2 Z-score was 44.8% in 2014, and increased to 50.7% in 2015 (P <0.001). The prevalence of WAZ was 18.5% in 2014, and 15.4% in 2015 (P<0.001). The prevalence of WHZ was 7.3% in 2014, and 4.1% in 2015 (P<0.001).
Georgiadis et al., 2021	Ethiopia, India, Peru, Vietnam.	Children 1, 5, 8, 12 and 15 years.	2000 children	Survey data from Young Lives, an international cohort study of childhood poverty in Ethiopia, India, Peru and Vietnam. Global Climate Database of the University of Delaware. Primary caregiver filled out the survey. Primary and secondary data.	Not specified.	Not specified.	To investigate 1.) the effect of maternal undernutrition in adolescence on offspring growth 2.) the pathways 3.) the rainfall shocks during the mother's adolescent years on maternal adult height and child growth.	Community rainfall shocks (cm), during mother's adolescence as instruments for mother's adolescence nutritional status. Defined as deviations from long-run community and season combined average and year-specific average.	HAZ <2SD Child Growth Standards median and stunting indicated as poor growth.	Longitudinal cohort. No control: effects for groups not exposed to rainfall shock not explicitly examined.	2002, 2006, 2009, 2012, 2015	Sign impact of rainfall shocks during mother's early adolescence on child growth from infancy to adolescence. Significant negative effect of rainfall shocks during the period when mothers were between 12 and 13 years old on maternal adult height. Therefore, additional analyses were conducted for mothers age 13 during the rainfall shock only. When the mother was aged 13 when being exposed to rainfall abnormalities: 1 unit increase (in cm) in rainfall causes 0.0005 increase in SD child height relative to a child of the same age and gender, but not sign However, when corrected by *sex* and child age.
Haileamlak et al., 2003	Ethiopia (Somali).	98% Children under 5 years, majority 24 months.	323 children	Questionnaire from record data obtained by nurses and questionnaire data from caregivers about their children.	Study conducted with children from Gode Hospital located in Somali region. Most households are pastorals. in the hospitals, the Government and international community provided relief activities like dry ration distribution and opening of feeding centers.	Ethiopia experienced prolonged drought and famine during 1997-2000 resulting in severe food shortage especially in southeast Ethiopia.	To investigate the profile and outcome of pediatric admissions to Gode Hospital during the relief activities in the year 2000.	No specific drought metric. The study is conducted within drought context, 1997-2000.	-Severe PEM (WAZ with edema), -WAZ <60% or -WHZ<70% on Harvard curve, -Mortality.	Cross-sectional study. No control.	April - August 2000	23% percent of the admissions were underweight WAZ (60% - 80%) and 64% severely malnourished (WAZ<60%). The overall mortality was 18% with case fatality rate of 23% for severe PEM.
Hirvonen et al., 2020	Ethiopia (all regions, excluding Addis Ababa).	Children 6 - 59 months.	About 3582 children. Subgroups: 1913 (HAZ) in 2014, 1998 (WAZ) in 2014 and 1745 (HAZ) in 2016, 1854 (WAZ) in 2016.	Survey data from ESS and rainfall estimates from CHIRPS.	Failure of two consecutive rainy seasons, poor harvests in the eastern parts of the country, >10 million Ethiopians needed food aid. The grain production decrease was variable throughout the country. Mainly the regions were affected that has low food security from the start. Cereal prices stayed relatively stable.	In 2015, Ethiopia experienced one of its worst El Niño induced drought. Central and northeast parts were particularly severely hit. The total rainfall during the meher was well below historical averages.	To investigate the impact of drought in 2015 on child malnutrition.	-Main drought measure: rainfall deviation. Rainfall deviation over one month. Z score deviation. during the meher season (JJAS), in relation to long-term average in the same locality. Drought-exposed areas: annual rainfall during the meher season was below −2 SD. -The normalized difference Vegetation Index (NDVI).	HAZ and WHZ <-2 Z-scores (continuous variable). Stunting and wasting also included as binary variable (yes/no).	Cross-sectional repeated measures using longitudinal data. With control: children unexposed to 2015 drought. For both arms, there are observations before (2014) and after (2016) the drought. Changes in anthropometric outcomes in 2014 and 2016 can be compared between treatment and non treatment group.	2014, 2016	-Drought did not lead to widespread increases in child undernutrition (HAZ 0.035 difference between drought exposed and non exposed, not sign; WHZ difference -0.068 not sign; stunted (0/1/): 0.006, not sign; wasted (0/1/) difference 0.022, not sign). -Additionally, HAZ increased after 2015 drought (more negative), but not sign. also after controlling for confounders. -WHZ on the other hand more positive values when exposed to drought (counterintuitive, but not sign). -Stunting & wasting as binary variable also provided no sign results. -Both drought metrics showed no sign results. -Moreover, distributions lie almost on top of each other again suggesting that the 2015 drought did not have a widespread impact on children's HAZ scores. Fig. 4b shows the same for WHZ. -Regression linen are nearly flat implying that children residing in drought exposed areas did not have worse HAZ scores in 2016 compared to children who were not (or were less) exposed to the 2015 drought. -Regressions based on WHZ also shows a relatively a flat relationship between WHZ and rainfall Z-score, -No statistical sign difference between wasting and stunting in 2014 between drought-exposed and non drought-exposed. 2015 drought had an impact on child height. (age and sex adjusted) heights, but confidence intervals were wide.
Kaluski et al., 2002	Ethiopia	Children under 5 years.	A bit unclear, varying numbers. Presumably 10449 children.	National and localized survey data from DPPC, the Ethiopian CSA, the WFP, UNICEF, Medline and direct contacts with associations, institutions and people concerned with food security in Ethiopia. Secondary	Recent war between Ethiopia and Eritrea began in May 1998. Since 1970s: damage to crops and erosion of soils. Stress on traditional coping strategies. Chronic poverty. These underlying pressures increased impacts of the 1998/99 drought. The famine should not be considered as a single pressure, but really in context of multiple hazards and	Failure of the belg rains, and other environmental hazards (crop failure, pests/weed investigations, war, poverty).	To investigate the famine and the food aid program in 1999±2000 by using the conceptual framework of food and nutrition security.	Study conducted right after a severe drought in 1998/1999 (context).	HAZ< 2SD, wasting and micronutrient deficiency: vitamin A, iodine, iron, zinc deficiencies.	Cross-sectional, mainly descriptive. No control.	Unclear	2000, higher prevalence of malnutrition compared to 1992. In 2000: 51% of children under 5 years had a HAZ < 2 SD and 26.3% < 3SD. Food security alone not the only factor responsible for malnutrition. Lack of coordination, harmonization and providing help on time. food aid did not met the needs for macro and micronutrients. recommendation: more diverse provision of food, medication, better sanitation and agricultural development.

				data.	structural problems. 1960s: food aid delivery. 8 million people received this in1999/2000.							
Ledlie et al., 2018	Ethiopia (all regions except 3 zones of Afar and 6 zones of Somali region).	Children 6–59 months	2659 households with a child.	Survey data, as part of the LMSMS-ISA project of the world bank. Monthly rainfall data for years 2011 and 2013.	Rural, small holder farms.	Not specified, deviation in rainfall in a drought prone country.	To investigate whether rainfall anomalies impact wasting prevalence (on short and long term).	Rainfall shock defined for (JJAS). -Rainfall z-scores: Number of SD from the 13-year average mean. -Binary variable < 90% rain/ fall of more than 10%.	WHZ <2 SD.	Repeated measures cross-sectional, no control.	2011, 2013	No sign results of rainfall shock on wasting. Coëfficiënt are small.
Mason et al., 2010	Ethiopia (Afar, Somali and Amhara, Oromia, SNNPR, Tigray) Kenya, Somalia, Sudan, and Southern Uganda.	Children under 5 years or <110 cm in height.	900 surveys. 316 children.	Malnutrition data same as Chotard et al. Drought data: FAO. Secondary data.	Emergency context. Urban areas and internally displaced people are excluded. Semi-arid and arid regions, vulnerable areas, separate analysis for pastoralists (lowlands), agriculturalists (highlands). Area known for conflicts.	2000: severe drought 2003: no drought but a flood. 2005: severe drought.	To investigate what interventions there should be in emergency situations such as drought, by analyzing malnutrition and mortality outcomes.	Drought on a scale (0 to 5, good to severe).	-GAM: acute malnutrition prevalence (WHZ + edema) - U5MR (child deaths/10,000/ day).	Time series, repeated cross-sectional, mortality rates obtained by 90 days recall. No control.	2000-2005	Relatively informal assessment: generally, drought leads to increased GAM and U5MR. *-Somali/Rift valley (Kenya), both pastoral* • 2000: 40% GAM, U5MR: 4/10,000/day. • 2001: lower prevalence • 2002: higher prevalence beginning of the year • 2003: no drought but flood. High GAM prevalence (30%-40%) and U5MRs (up to 5/10,000/day) due to flood. • 2004-2005: scarcity of drought reports in 2004–05. • 2005: drought caused higher GAM and U5MR again. *-Oromia, agricultural, less drought prone, fig 2e:* • 2000: < 15% GAM prevalence, U5MR: <1/10,000/day • 2001: data scarcity, but U5MR better reflects the effect of drought • 2002: (mid 2002) drought returned a bit causing slightly increased prevalence. data scarcity, but U5MR better reflects the effect of drought • 2003: scarcity of drought reports in 2003, 2004, 2005. Conclusion: effects between drought, food security, malnutrition and mortality stronger in pastoralists. GAM good predictor of mortality risk.
Mekonnen et al., 2022	Ethiopia. Focus areas Ethiopia: Dangila and Bahir-Dar Zuria in Amhara, Lemo in SNNP and Adami Tulu in Oromia. Tanzania.	Children under 5 years	442 households461 children	Survey data using panel data collected as part of ILSSI. Primary data.	Only 5% of Ethiopia's cultivated area of 16 million ha is currently equipped for irrigation. 17% of area has the potential to be irrigated. Demonstrations took place between Dec 2016 and Jan 2017.	-	To investigate the effectiveness of an irrigation intervention on child malnutrition in a drought shock setting.	Experience of a drought shock 5 years before baseline or between 2014 and 2017, measured by self-reporting through household survey.	WHZ, HAZ, <-2 Z-scores, wasting and stunting (binary 0/1)	Longitudinal panel study, quasi experimental. With control: irrigators and non irrigators.	Nov 2014, Feb 2017	If drought occurred (binary 1/0), than 0.155 higher prevalence score of wasting (sign). Normal conditions: Irrigation improves WHZ by 0.87 SDs. Drought conditions: Ethiopian households who faced drought, women in irrigating households have higher Women's Dietary Diversity Score (WDDS) compared to women in non irrigating households.
Tesfaye et al., 2022	Ethiopia	Children under 5 years	4726 children	Survey data from ESS collected by LSMS-ISA, the World Bank in collaboration with CSA. Household data is linked with georeferenced climate (historical rainfall) from CHIRPS.	Smallholder farms in a developing country context.	Drought shock, defined as children living in areas that experience drought.	To investigate the impact of crop diversification on child growth and whether the effect is changed by drought shocks.	-Drought shock (binary 0/1). -Monthly average Rainfall and max monthly temp data. Rainfall data extracted from 2001- 2015 to calculate the historical average and SD of rainfall, a proxy for long-term rainfall variability. Annual temperature data. extracted three months before the collection of DHS data on the nutritional status of children.	-WHZ, HAZ, <-2 Z-scores & binary (0/1).	Longitudinal panel study. No control.	2011/12, 2013/14, 2015/16	Drought shock: the results show that crop diversification (Shannon index and nr) has a positive but small impact and non sign on child growth (CI overlap) by reducing the risk of stunting and wasting. Children in areas that experience drought do not have less severe malnutrition conditions.
de Waal et al., 2006	Ethiopia, excluding Afar and Somali.	Children under 5 years	4816 households. Children not specified.	Survey data ECSS-2004: -Randomly selected sites from an ongoing panel into socio-economic well-being conducted by UAA and ACEHS. Rural and urban sites, some sites affected by drought, others not. -Randomly selected sites affected by drought as described by the WFP. Rural only. Primary data.	Rural and urban sites. Excluding pastoralist and semi-pastoralist populations in the Eastern periphery of the country. Drought affected 13.2 million people. JJAS 2002. Aid was focused on the regions with high mortality rates at the start of 2002. Compound hazards: not only drought but structural other chronic conditions were underlying.	Drought in 2002/03, rainfall shortage.	To investigate the impact of drought on child mortality rates.	Children affected by the 2002-03 drought vs children not affected by this drought.	Three month retrospective mortality rates, expressed as the number of deaths per 1,000 live births per year.	Retrospective cross-sectional. No control but areas that faced drought and areas that did not face drought are included.	Apr - Jun 2004	Mortality rates were higher among drought affected areas: 158 death per 1000 vs 121 per 1000. Underlying mechanism is probably due to interplay of chronic hazard events and high levels of malnutrition historically in this region. Drought in 2002-2003 did not have a sign marginal effect on mortality (coefficient 0.00241, p=0.802), while a lot of others variables did, such as the age of the mother at birth (0.00761, p=0.0130 Total percentage of stunting (chronic malnutrition) is 57% (including drought and non drought areas). Higher percentage of stunting in drought affected areas (exact numbers are not given).

Abbreviations: LSMS-ISA, living standards measurement study-integrated surveys on agriculture; ILSSI, feed the future innovation laboratory for small scale irrigation; UCDP GED, uppsala conflict data program georeferenced event dataset; MODIS, moderate resolution imaging spectroradiometer; ECSS, Ethiopia child survival survey; UAA, University of Addis Ababa.

Hagos et al., 2014	Ethiopia	Children under 5 years	145 observations.	Survey data from agricultural Sample and DHS-1996 to 2004 collected by the CSA were used for malnutrition data and crop data. Rainfall data from weather stations. Altitude data downloaded from climate data source. Temp data obtained from the CRU time-series datasets. Secondary data.	Limited details are provided. The harvest season included October and November in the study locations.	Drought in 1996–2004 characterized by low and untimely rainfall. The average growing season rainfall of the study locations was 645.2 mm.	To investigate the impact of rainfall and temp variability on child malnutrition at local scale during before and after a drought event in 1999-2000.	-Monthly rainfall data pre harvest season JJAS -Temperature.	HAZ, WAZ, WHZ -<SD moderate malnutrition, -<3SD severe malnutrition.	Longitudinal panel study. No control.	1996, 1998, 2000, 2004	-One SD increase in rainfall leads to 0.242 SD increase in moderate stunting (sign). -One SD increase temperature leads to 0.216 SD decrease in moderate stunting (sign). -However, moderate wasting and underweight were found to be poorly related with rainfall and temperature. -Severe wasting showed a positive relationship with the quadratic term of rainfall in all zones. -The results of the study demonstrate that temperature has a sign effect on child underweight and stunting. Conclusion: rainfall and temperature partly predict variations in child stunting and underweight. Models vary in predicting stunting and underweight across the three agro-ecologic zones. This could indicate that a single model for the three agro-ecologies may not be sufficient/reliable.
Salama et al., 2001	Ethiopia (Gode district in Somali)	Children 6 months to 5 years	4032 household members. 25.3% = children under 5	Survey data conducted by Save the Children USA, UN children's Fund and the Centers for Disease Control and Prevention.	>10 million people in need of food assistance during drought. May 2000, rapid humanitarian response presumably diminished the impact. Compound hazards: Descriptions of civil conflict and extremely poor health infrastructure. Measles illness.	Drought between Dec 1999-Jul 2000 dec, resulting in a famine.	To investigate child mortality rates and malnutrition prevalence in Gode district during a drought-induced famine.	No specific drought metric. The study is conducted within drought context, 1999-2000.	8-month retrospective mortality rates and malnutrition outcomes (WHZ <2SD moderate wasting, WHZ <-3SD or WHZ+edema severe wasting, Causes of death are also described. Primary data.	Cross-sectional, no control.	Jul - Aug 2000	*Malnutrition and mortality rates:* -The mortality rate for children under 5 was 6.8/10 000 per day (95% CI, 5.4-8.2/10 000 per day). 72.3% due to wasting. -77% of death occurred before interventions in April/May 2000. The prevalence rate for wasting (WHZ –2 score) was 29.1% (95% CI, 24.7%-33.4%). The mean WHZ was −1.53 (95% CI, −1.60 to −1.46). -8 months after the famine began, 29.1% (95% CI, 24.7%-33.4%) had wasting; 23.4%; 95% CI, 19.7%-27.0%) had moderate wasting and 49 (5.7%; 95% CI, 4.1%-7.3%) had severe wasting. -4.7% of well-nourished children had measles. 70% of death due to wasting alone or together with measles or other communicable disease. .

Appendix E. Criteria for the risk of bias assessment

This risk of bias assessment was based on (Johnson. et al., 2014) and modified to fit the topic of this thesis. The domain 'Other bias' was removed as this is a quite broad term and this domain was assessed with 'low risk of bias' in all 27 individual papers in (Belesova et al., 2019). Therefore is was assumed that the added value of this domain is low.

1. Selection strategy

1.1 Criteria for a judgement: low risk of bias

The judgement "Low risk of bias" is given when it is described how study participants are selected (recruited and sampled). This ensures that participants are representative for the study population. When control groups are used in the study - meaning multiple arms are used or when multiple measurement waves are conducted - the procedure of sampling and recruiting is the same for all groups.

1.2 Criteria for a judgement: probably low risk of bias

Sufficient details about the selection of participants are lacking. Therefore, it is not possible to assess the selection strategy as 'low risk of bias'. However, the paper gives the impression that there is probably low risk of bias, when relying on the descriptions of relevant other variables, participants and/or procedures. It seems that the author is aware of potential sources of bias due to the recruitment strategy.

1.3 Criteria for a judgement: probably high risk of bias

Sufficient details about the selection of participants are lacking. Therefore, it is not possible to assess the recruitment strategy as 'high risk of bias'. However, the paper gives the impression that there is probably high risk of bias, when relying on the descriptions of relevant other variables, participants and/or procedures. It seems that the author is not aware of potential sources of bias due to the recruitment strategy.

1.4 Criteria for a judgement: high risk of bias

The judgement "high risk of bias" is given when there are no descriptions of how study participants were selected. Or when the selection procedure is not consistent among different groups.

1.5 Criteria for a judgement: not applicable

It is proven that the recruitment strategy can by definition not introduce bias in the study. For instance, when a population register is used that contains information about every single citizen in a certain city, the sample taken from this population is than by definition representative. Alternatively, selection of participants was not crucial for this study design.

2. Blinding

2.1 Criteria for a judgement: Low risk of bias

The judgement "low risk of bias" is given when 1.) there is no blinding but it is assumed by the authors that the lack of blinding does not have substantial consequences for the study outcome and therefore does not introduce bias, 2.) when there was blinding of the most important researchers and/or support staff and there was high probability that this procedure did not introduce bias, 3.) A number of important researchers and/or supportive staff was not blinded but the outcome assessment was. There was high probability that this did not introduce bias.

2.2 Criteria for a judgement: probably low risk of bias

Sufficient details about blinding are lacking. Therefore, it is not possible to assess blinding as 'low risk of bias'. However, the study gives the impression that there is probably low risk of bias due to blinding, when relying on indirect other variables.

2.3 Criteria for a judgement: probably high risk of bias

Sufficient details about blinding are lacking. Therefore, it is not possible to assess blinding as 'high risk of bias'. However, the study gives the impression that there is probably high risk of bias, when relying on indirect other variables.

2.4 Criteria for a judgement: high risk of bias

The judgement "low risk of bias" is given when 1.) there is no blinding but it is likely that the lack of blinding does not have substantial consequences for the study outcome and therefore there is a high likelihood of bias 2.) when there was blinding of the most important researchers and/or support staff but still a high probability that introduced bias or 3.) A number of important researchers and/or supportive staff was not blinded although the outcome assessment was. There was still a high probability that this did introduce bias into the research.

2.5 Criteria for a judgement: not applicable

It is proven that blinding can by definition not introduce bias in the study. Or when blinding does not play a role in the study design.

3. Exposure assessment

The focus was on the assessment of drought, as not all studies had an intervention as exposure.

3.1 Criteria for a judgement: Low risk of bias

The judgement "Low risk of bias" is given when there is a clear distinction between the group that is exposed to drought and the group that is not exposed to drought and this is determined by the authors of the study making use of clear drought metrics. For instance, decreased precipitation levels. Drought metrics are supported by reference material of the designated proxy. For instance, WHO is mentioned as a source.

In case that no direct drought metric is present, the judgement "low risk of bias" is given when sufficient details are given that the drought was not just a seasonal variation but a real deviations from normal circumstances.

3.2 Criteria for a judgement: probably low risk of bias

Sufficient details about the exposure variable or drought context are lacking. Therefore, it is not possible to assess the exposure as 'low risk of bias'. However, the paper gives the impression that there is probably *low* risk of bias, when relying on (indirect) other variables. For instance, it is mentioned that drought was acknowledged by the government, but there is not referred to a specific assessment. Or when drought exposure was self-reported, but validity checks were done.

3.3 Criteria for a judgement: probably high risk of bias

Sufficient details about the exposure variable or drought context are lacking. Therefore, it is not possible to assess the exposure as 'low risk of bias'. However, the paper gives the impression that there is probably *high* risk of bias, when relying on (indirect) other variables. For instance, there is a news article that announced that there was a drought in a specific capital, but that was not specific for a the study area. Or for instance because there are a lot of missing values.

3.4 Criteria for a judgement: high risk of bias

The judgement "high risk of bias" is given when the exposure metric 1.) relied on retrospective data causing recall bias 2.) is reported by a metric that has a high probability of introducing bias in the study 3.) was not backed up by data 4.) was backed up by non specific data e.g. price spikes.

In case that no direct drought metric is present and the study was during a drought event instead, the judgement "high risk of bias" is given when drought context was inconsistently described, when drought events cannot be distinguished from seasonal variations or real deviations from normal circumstances.

4. Confounding

Confounders are factors that are related to both the outcome and exposure that can potentially distort the association between exposure and outcome variables (Jager et al., 2008).

4.1 Criteria for a judgement: Low risk of bias

The judgement "Low risk of bias" is given when the most important confounding factors are addressed, controlled for, adjusted for or matched by. The judgement is also given when a multivariate analysis is conducted. Alternatively, the judgement is given when there is controlled for confounding factors but removed later because the inclusion of confounding factors did not really influence the results of the study.

4.2 Criteria for a judgement: probably low risk of bias

Some important confounding factors are introduced in the model, not all important ones. However, lack of all important factors is assumed not to introduce bias in the study. For instance, when exposure (drought) is measured on province level instead of national level, this will minimize the disturbing impact of other variables on the association with malnutrition. Or for instance, because it is expected that variables that were not controlled for are correlated to some confounders included in the model already. Therefore, the risk of bias will not be large. For instance, 'distance to health care facility' could be related to 'poor road quality'.

4.3 Criteria for a judgement: probably high risk of bias

Some important confounding factors are introduced in the model, not all important ones. This could have introduced bias into the study. For instance, there could be controlling for confounding at the individual level, but not having considered the confounding for distorting variables between exposure and outcome. Or for instance, authors could have mentioned that there is risk on bias.

4.4 Criteria for a judgement: high risk of bias

The judgement "high risk of bias" was given when the authors of the study did not control for confounding factors.

4.5 Criteria for a judgement: not applicable

It is proven that confounding can by definition not introduce bias in the study. For instance because the study design randomized study participant (RCT). Or for instance because a single cross-sectional study design was used that provided prevalence only and not associations between exposure and outcomes. In the latter case, there can be definition be no factors that are associated with the exposure and outcome variable.

5. Outcome data

5.1 Criteria for a judgement: Low risk of bias

The judgement "low risk of bias" is given when the outcome metric is suitable (measures malnutrition) and well defined (cut-off values provided). For instance, the weight-for-height *Z-score* is used instead of just weight in kg, or height in cm. When the outcome metric is categorical, clear category cut-off values (standard outcome measures) should be provided. For instance, a WHZ <-2 is defined as moderate wasting. A clear outcome metric is for instance the WHZ values according to WHO standards.

5.2 Criteria for a judgement: probably low risk of bias

Sufficient details about the outcome metric are lacking. Therefore, it is not possible to assess the outcome as 'low risk of bias'. However, the paper gives the impression that there is probably *low* risk of bias, when relying on (indirect) other variables.

5.3 Criteria for a judgement: probably high risk of bias

Sufficient details about the outcome metric are lacking. Therefore, it is not possible to assess the outcome as 'high risk of bias'. However, the paper gives the impression that there is probably *high* risk of bias, when relying on (indirect) other variables.

5.4 Criteria for a judgement: high risk of bias

The judgement "high risk of bias" is given when 1.) no standard cut-off levels are used, 2.) less appropriate metrics are used such as growth instead of HAZ, 3.) the procedure or source of outcome data generation is unknown. 4.) For instance, when micronutrients deficiency is diagnosed based on children's clinical appearance only.

5.5 Criteria for a judgement: unclear

No information about anthropogenic measurements was provided.

6. Selective reporting

6.1 Criteria for a judgement: Low risk of bias

All study outcomes as mentioned in the abstract, method and or introduction are adequately reported in the result section.

6.2 Criteria for a judgement: probably low risk of bias

Sufficient details about the outcome metric are lacking. Therefore, it is not possible to assess the outcome as 'low risk of bias'. However, the paper gives the impression that most outcomes are reported in the results section.

6.3 Criteria for a judgement: probably high risk of bias

Sufficient details about the outcome metric are lacking. Therefore, it is not possible to assess the outcome as 'high risk of bias'. However, the paper gives the impression that most outcomes are not reported in the results section.

6.4 Criteria for a judgement: high risk of bias

The judgement 'high risk of bias' is given when 1.) not all primary outcomes that are mentioned in the abstract, methods and/or introduction are mentioned, or 2.) some of the primary outcomes were reported, but by having used non previously specified measurement instrument or analyses procedures.

6.5 Criteria for a judgement: not applicable

Outcome metrics were not reported at all.

7. Conflict of interest

7.1 Criteria for a judgement: Low risk of bias

It is clear that the study was free of support from any kind of entity with financial interest. This means that the researchers were not working for the governments an NGO or a banks and it is unlikely that the researchers were involved in any financial interest regarding the study outcome. Additionally, conflict of interest is judged with 'low risk of bias' when the authors explicitly state that they are not involved in any

kind of financial interest regarding the outcome of the study. And when funding is only received from government or academic institutions.

7.2 Criteria for a judgement: probably low risk of bias

Sufficient details about conflicts of interest are lacking. Therefore, it is not possible to assess conflict of interest as 'low risk of bias'. However, the paper gives the impression or there is indirect evidence that there is probably low risk of bias, when relying on the descriptions of relevant other variables, participants and/or procedures. For instance, when entities are involved in conducting/analyzing/recruiting participants, but they did not have any interest in the outcome.

7.3 Criteria for a judgement: probably high risk of bias

Sufficient details about conflicts of interest are lacking. Therefore, it is not possible to assess conflict of interest as 'high risk of bias'. However, the paper gives the impression or there is indirect evidence that there is probably high risk of bias, for instance, when entities are involved in conducting/analyzing/recruiting participants and it is not stated that they did not have any interest.

7.4 Criteria for a judgement: high risk of bias

The judgement high risk of bias was given when 1.) the authors mention that there was conflict of interest, or 2.) material was provided for free by entities with financial interest, or 3.) writing help was provided by entities with financial interest, or 4.) authors were employee at entities that have financial interest, or 5.) there was provision of research funds by entities with financial interest.

7.5 Criteria for a judgement: Unclear.

No information is provided at all.

Overall risk of bias assessment

The overall ROB judgement is based on the following guidelines:

- *Low risk of bias:* at least all categories are assessed (probably) low risk of bias.
- *High risk of bias:* at least 1 domain assessed as (probably) high risk of bias.
- *Some concerns:* everything in between.

Note: >2 domains assessed unclear while all other domains are assessed low risk: some concerns.

Appendix F. Summary risk of bias assessment in individual studies

Table S1. Risk of bias summary for M. Bakhtsiyarava et al., 2021

Domain	Assessment	Reasoning
Selection strategy	Probably low risk of bias	High inequality in the number of participants in study arms. Recruitment strategy not described. Data obtained from surveys. It is mentioned that participants are representative for people living the 4 study regions.
Blinding of the outcome measurement	Probably low risk of bias	No blinding strategies have been described. However, outcome data from the Ethiopia Socioeconomic survey was used and it is assumed that this procedure did not introduce bias. data is used that already existed.
Exposure assessment	Probably low risk of bias	The variable 'rainfall anomalies' is created by computing variables and combing them using a formula (transparent). It seems that data on different aggregation levels is used (survey results based on household data and climate data based on village data), but that seems alright as climate data is not household specific. Exposure of production diversity and composition are computed based on questionnaires and might therefore be prone to recall bias. The house hold dietary diversity score, that was part of the farm production diversity score, included a number of food groups.
Confounding	Probably high risk of bias	The fixed effect design controls for time-invariant measures meaning that it compensates for not being able to control for all time-invariant factors.
Outcome data	Low risk of bias	Appropriate outcome measures are used (WHZ, HAZ scores) and assessed against the WHO guidelines. However, WHZ is a chronic malnutrition metric and therefore long term exposure metrics such as household food security on WHZ might not be measurable yet (in contrast to HAZ). There is awareness about this by the authors.
Selective reporting	Low risk of bias	All outcomes that are mentioned in the abstract, introduction and methods are also analyzed and reported in the results section.
Conflict of interest	Low risk of bias	The authors acknowledge having received funding from a governmental organization (National science foundation INFEWS) and the authors mentioned to have processed the data, to have performed statistical analyses and to have written the paper independently.

Table S2. Risk of bias summary for Chotard et al., 2010

Domain	Assessment	Reasoning
Selection strategy	Probably low risk of bias	Recruitment of participants is not mentioned. However, survey sampling is described. Mostly, the same sampling technique is used. Generally a standard procedure is used.
Blinding of the outcome measurement	Probably low risk of bias	Blinding has not been described. However, outcome data from DHS was used and it is assumed that this procedure did not introduce bias. Data was collected that already existed.
Exposure assessment	Probably high risk of bias	The month of the season was not always recorded. Drought was not always recorded in the surveys. Furthermore, The authors mentioned that drought was not reported consistently. Drought did not contain a lot of missing values though compared to the other risk factors. Was collected at the national level, not representative of the local scale. The fact that drought levels are collected on national level could introduce bias.
Confounding	Probably high risk of bias	Regression analyses were adjusted only for season and livelihood type, SES and country. Other confounders could have been assessed well. This might have introduced bias.
Outcome data	Probably low risk of bias	Global acute malnutrition is a combination of edema and wasting and bias could be introduced because it might not give a clear estimation of the single wasting prevalence. However, edema contributes only a small extend to the outcome (0.8%), suggesting that there is low risk of bias.
Selective reporting	Low risk of bias	All outcomes that are mentioned in the title/abstract, introduction and or methods have been reported. Cases with missing values were excluded from the analysis.
Conflict of interest	Low risk of bias	Help received from universities and non profit organizations. Surveys were conducted by the Government, sometimes with non-governmental organizations. These non-governmental organizations were interpreted as having no financial interest with regards to the study outcome.

Table S3. Risk of bias summary for S. Dercon et al., 2014

Domain	Assessment	Reasoning
Selection strategy	Low risk of bias	Recruitment is not reported. Sampling strategy within house holds was described (random sampling), with low attrition rates. There was awareness of authors that rounding of age could have introduced bias. They mentioned what strategies they applied to reduce fertility and mortality bias.
Blinding of the outcome measurement	Probably low risk of bias	The authors did not explicitly state what their blinding strategy was. However, outcome data from the 6th round of ERHS was used and it is assumed that this procedure did not introduce bias. Data is used that already existed. Furthermore, they tried several different estimation techniques.
Exposure assessment	Probably low risk of bias	Drought famine on the BBC news. Drought is calculated compared to a long term average. However, at least a part of the drought is self-reported . The authors already mentioned themselves: there could be endogeneity bias because drought is self-reported. Authors are aware of this.
Confounding	Probably low risk of bias	Adjusted for several variables. Separate cross sectional model to take into account confounding. The benefit of this study design on household level is that it can separate drought from other shocks a bit better (compared to data collection at geographical levels).
Outcome data	High risk of bias	Outcome measure is height and not HAZ. Also not referred to a standard measure against the WHO for instance. Height data is collected via a survey and measured in cm. Not mentioned how it is collected (self reported or by staff).
Selective reporting	Low risk of bias	The author mentioned that there was no evidence for selective reporting. It seems that all outcomes mentioned in the abstract, introduction and methods sections are also reported in the result section.
Conflict of interest	Probably low risk of bias	Data collected by the University of Addis Ababa together with other policy institutions (CSAE). Funding for the surveys was also provided by councils (USAID and SIDA) that were assumed to not have a financial interest in the outcome of the study. A list of people and two anonymous reviewers gave feedback for paper improvement.

Table S4. Risk of bias summary for A. Dimitrova et al., 2021

Domain	Assessment	Reasoning
Selection strategy	Probably low risk of bias	Recruitment strategy not mentioned. A two-stage cluster sampling procedure was done.
Blinding of the outcome measurement	Probably low risk of bias	Binding has not been described. However, outcome data from DHS was used and it is assumed that this procedure did not introduce bias. This type of data is collected every year and already existed. Anthropometric data was used.
Exposure assessment	Low risk of bias	Drought measured by SPEI, which is a metric that is often used and is reliable.
Confounding	Probably low risk of bias	Several control variables were mentioned: gender, higher birth order, twin births. Better education of the mother and a higher wealth status employment in the agricultural sector. Drought measured at regional level, therefore distortion of other variables is assumed minimal.
Outcome data	Low risk of bias	Standardized measures are used, WHZ, against the WHO guidelines.
Selective reporting	Low risk of bias	All variables mentioned in the abstract and introduction are also mentioned in the result section.
Conflict of interest	Low risk of bias	The author explicitly mentioned that no entities with financial interest were involved in the study

Table S5. Risk of bias summary for S. Doocy et al., 2005

Domain	Assessment	Reasoning
Selection strategy	Low risk of bias	Participants were selected from the client lists and described with a sufficient amount of detail. Recruitment of controls is also described. Most of the time, consistent strategies were used among groups. Participants were enrolled in the WISDOM group over a long period of time. This could have altered the characteristics of the study population and thereby introducing bias into the study. However, different strategies were applied to reduce this type of bias, amongst other the use of multiple control groups and analyzing different characteristics between participants.
Blinding of the outcome measurement	Low risk of bias	Research staff/interviewers received training to do interviews, more details are provided in the original paper.
Exposure assessment	Probably high risk of bias	Drought event context 2003 is described but not quantified and not specified per region, while this study focused on specific regions and not only on national level.
Confounding	Not applicable	Cross-sectional study. No association between drought and malnutrition investigated. Prevalence is identified.
Outcome data	Probably low risk of bias	It is described that MUAC is acceptable, and a more practical measure comparable to BMI (Semba & Bloem, 2001). Cut-off values are provided which suggest that this is a reliable metric to use. Cooping capacity was self reported.
Selective reporting	Low risk of bias	All the outcomes measured in the introduction abstract and or method section are also reported in the results section.
Conflict of interest	Unclear	The authors did not explicitly mention that no entities with financial interest were involved in the study. It is not mentioned whether staff was involved in any stage of the research.

Table S6. Risk of bias summary for T. Gari et al., 2017

Domain	Assessment	Reasoning
Selection strategy	Low risk of bias	There is referred to the initial recruitment strategy of the RCT (Deressa et al., 2016). The sample seems to be a representative study population. Participants were selected randomly.
Blinding of the outcome measurement	Low risk of bias	Nothing mentioned about blinding in this paper. However, outcome data was used from a previous trial and adequately described. Anemia was diagnosed using HemoCue Hb 30.
Exposure assessment	Probably low risk of bias	This study took place during the 2015 drought. There is evidence that the 2015 drought was a real drought: annual rainfall was 673 mm in 2011, 909 mm in 2012, 745 mm in 2013, 673 mm in 2014 and decreased to 471 mm in 2015.
Confounding	Not applicable	This study is a combined cross-sectional and cohort study. Since the cohort study was disregarded, this study was not applicable for confounding assessment. Only prevalence was taken into account here.
Outcome data	Low risk of bias	WHO criteria for WAZ, WHZ, HAZ and anemia were used, and standard cut-off values were mentioned.
Selective reporting	Low risk of bias	Outcomes that were mentioned in the introduction, abstract and methods section were also mentioned in the results section.
Conflict of interest	Low risk of bias	Funding was provided by a Norwegian research council. Other support was provided by universities and other research councils suggesting that no entities with financial interest were involved in this study.

Table S7. Risk of bias summary for A. Georgiadis et al., 2021

Domain	Assessment	Reasoning
Recruitment strategy	Low risk of bias	The recruitment strategy is partly described. The researchers mentioned that they used data from a pre existing cohort study Young Lives. It is explained what the researchers did with missing values and outliers.
Blinding of the outcome measurement	Probably low risk of bias.	No specific blinding strategies have been described. However, survey data used from Young Lives, an international cohort study. Sufficient details are provided (Barnett et al., 2013)
Exposure assessment	Probably low risk of bias	The authors mentioned that rainfall shock data during mothers' adolescence did not risk bias because rainfall shock data is not correlated with numerous other relevant variables. And the author explicitly mentioned that this will limit measurement error. Not clearly mentioned if positive rain shock failures are referring to periods of drought or periods of increased rainfall.
Confounding	Probably low risk of bias	Controlled for child age, gender, mother's ethnicity, the language of administration of the test, and whether the test was administered in the child's mother tongue. More factors could have been added. Missing values for rain shock are included.
Outcome data	Low risk of bias	HAZ score against the WHO 2006 standards. Clear cut-off values are given.
Selective reporting	Low risk of bias	Values from the abstract and title and methods section are also reported in the results section.
Conflict of interest	Probably low risk of bias	Authors did not explicitly mention the (lack of) involvement of financial entities. However, the authors did mention several other research institutions that are involved in the research. I get the general idea that no financial interests are involved in this study.

Table S8. Risk of bias summary for A. Haileamlak et al., 2003

Domain	Assessment	Reasoning
Selection strategy	Probably low risk of bias	Details about recruitment strategy or sampling strategies not mentioned. Participants seem representable for the study population. All children were treated according to the WHO protocol for PEM.
Blinding of the outcome measurement	Probably low risk of bias	No specific blinding strategies have been described. However, a questionnaire from record data was obtained by trained nurses and questionnaire data from caregivers about their children.
Exposure assessment	Probably high risk of bias	It is described by the author that there was exposure to drought (context). Effect measures not provided. There is specific focus on Gode district, but drought was not measured in this specific area (but on natural level).
Confounding	Not applicable	The association between drought and malnutrition was not examined. Just the prevalence in a drought context was given.
Outcome data	Low risk of bias	Salter scale (gm) and length board (cm). Also there is referred to the Harvard curve for cut off values. PEM is combined by WAZ with edema, WAZ<60% or WHZ<70%.on Harvard curve.
Selective reporting	Low risk of bias	All outcomes mentioned in the introduction and methods section are also reported in the results section.
Conflict of interest	Probably low risk of bias	It is stated that a clinical program secretaries wrote the script. There is not explicitly mentioned whether this entity had financial interest but it is assumed for now that this entity did not have this. Furthermore, research institutes were involved in support with analyzing data. Nothing is written about funding.

Table S9. Risk of bias summary for K. Hirvonen et al., 2020

Domain	Assessment	Reasoning
Selection strategy	Probably low risk of bias	Recruitment strategy is not mentioned. Sampling: it is expected that the sample is representative as many geographical regions are included. The sampling of groups is done based on exposure or not exposed. Data is available for both the exposure and non exposure group.
Blinding of the outcome measurement	Low risk of bias	No specific blinding strategies have been described. However, survey data was used from an existing cohort.
Exposure assessment	Low risk of bias	Rainfall data utilized from the rain season JJAS. It has been described that Z scores are utilized to limit bias. Drought was defined as rainfall Z-scores. There is a clear distinction between the group exposed to drought and not to drought. There are clear drought metrics used and referred to the CHIRPS as the data source.
Confounding	Probably low risk of bias	The authors mention that they controlled for various factors that might disturb the association between drought and malnutrition. Examples are: dependency ratios, older household heads, better access to electricity and safe water sources and poorer access to toilets. There is also controlled for region-specific time trends in the regression. Furthermore, the authors also mentioned that they specifically did not include variables that may have been affected the treatment (drought). Otherwise, relations would be disturbed.
Outcome data	Low risk of bias	Malnutrition metrics were used against the WHO 2006 guidelines. Clear cut-off values are provided.
Selective reporting	Low risk of bias	Outcomes that are reported in the introduction, methods and or abstract are also reported in the results section.
Conflict of interest	Probably low risk of bias	Funding was provided by the Future of Agriculture in Ethiopia project, which in turn was funded by the European Union. Other entities that were involved were the Central Statistical Agency, the World Bank, and the Climate Hazards Group. Feedback was provided by the world bank.

Table S10. Risk of bias summary for D. Kaluski et al., 2002

Domain	Assessment	Reasoning
Selection strategy	Probably low risk of bias	Did not mentioned a lot of detail. The authors only mentioned what data sources they used. Unclear whether a representative population sample was used.
Blinding of the outcome measurement	Low risk of bias	No specific blinding strategies have been described. However, existing data is used. Secondary data. Authors mentioned that data was used from official information sources.
Exposure assessment	Probably high risk of bias	Not many details are provided about the drought event. Only the following was described: *'Failure of the belg rains (short rains from February to March.*
Confounding	Not applicable	Single cross-sectional study. No associations are provided.
Outcome data	High risk of bias	Standard cut-off values are used for a few malnutrition metrics, but not for all. Not referred to WHO or other source. Sometimes, the author referred to percentages instead of z values (inconsistent).
Selective reporting	Probably low risk of bias	All outcomes that are mentioned in the abstract, introduction and methods section are generally also mentioned in the results section. The results section is lacking a bit of structure though.
Conflict of interest	Probably low risk of bias	No details are provided about the provision of funding. However, the acknowledgement paragraph describes that the author wants to thank entities that do not have financial interest such as the DPPC/USAID professionals for their support. And also, other entities are thanked such as the Israeli Ambassador, Ministries of Foreign Affairs and Health.

Table S11. Risk of bias summary for N. Ledlie et al., 2018

Domain	Assessment	Reasoning
Selection strategy	Probably low risk of bias	Recruitment strategy was not mentioned. Sampling strategy not mentioned, but it seems that a representative study sample was used and that strategies were consistent.
Blinding of the outcome measurement	Probably low risk of bias	No specific blinding strategies have been described. However, survey data was used as part of the LMSMS-ISA project of the World Bank. Secondary data.
Exposure assessment	Probably low risk of bias	Clear exposure metric: rainfall Z-scores. And a binary variable with cut-off values (90%). It was not mentioned why a cut-off value of 90% was used.
Confounding	Probably low risk of bias	There was adjustment for important covariates. All models where adjusted for child sex, age, household size, parent's education and household wealth.
Outcome data	Low risk of bias	WHZ <2 SD against WHO standards.
Selective reporting	Low risk of bias	All outcomes that were mentioned in the abstract, introduction and or methods section were also mentioned in the results and discussion section.
Conflict of interest	Low risk of bias	Funding provided by the Bill and Melinda Gates Foundation. The authors themselves were responsible for writing the paper.

Table S12. Risk of bias summary for J. mason et al., 2010

Domain	Assessment	Reasoning
Selection strategy	Probably low risk of bias	The same as Chotard et al: Recruitment of participants is not mentioned. However, survey sampling is described. Mostly, the same sampling technique is used. Generally standard procedures are used.
Blinding of the outcome measurement	Low risk of bias	It was stated that the coding was done without knowing what the outcomes where. Assessments were conducted separately by two independent researchers.
Exposure assessment	Low risk of bias	It is stated that drought estimates are obtained from the FAO. Drought conditions were coded by 0-5 good to severe. Not mentioned how drought conditions were measured.
Confounding	High risk of bias	Nothing mentioned about confounding.
Outcome data	Probably low risk of bias	Mortality rates: large confidence intervals for mortality rates. But authors state that there is probably low risk of bias. GAM is a combination of WHZ plus edema. Seems a reliable indicator. Less than 1 percent normally has edema.
Selective reporting	Low risk of bias	All outcomes that were mentioned in the abstract, introduction and or methods section where also mentioned in the results section.
Conflict of interest	Low risk of bias	Collaborating entities where listed and it is assumed that the did not have financial interest in the study outcome (University, Safe the children, independent consultant, physician assistant, UNICEF). In the acknowledgement, it is stated that support was received from UNICEF and two other people (only their names where available, not the companies they are working for).

Table S13. Risk of bias summary for D. Mekonnen et al., 2022

Domain	Assessment	Reasoning
Selection strategy	Low risk of bias	It has been described that the allocation of sites for the intervention was based on a scoping research, no randomization. Authors are aware of this and emphasize that result should not be generalized to other regions. Which observations will be dropped is described as well.
Blinding of the outcome measurement	Probably high risk of bias	No specific blinding strategies have been described. Height measurements were conducted during home visits. There could have been bias due to blinding when researchers know of other participant characteristics. It is not mentioned in the text how researchers corrected for this.
Exposure assessment	Probably low risk of bias	Furthermore, drought was described in detail. Self-reported data.
Confounding	Low risk of bias	Regressions were controlled for a list of variables: access to irrigation, a dummy variable for the survey round, size of land ownership, number of adults in the household, ownership of cows, ownership of goats and sheep, ownership of chickens, remittances, self-employment income, whether the adult woman had a formal education, reported shocks such as storms, drought and floods, crop damage from pests and disease, and idiosyncratic shocks, such as death and illness of a household member. And also: including age in months, number of siblings under 5 years of age, whether the child was sick in the 2 weeks preceding the survey, and whether the child was exclusively breast-fed for the first 6 months.
Outcome data	Low risk of bias	WHZ, HAZ scores with clear cut-off values against WHO guidelines. Professionals were involved in conducting the anthropogenic measurements. Clear exclusion criteria were provided. Children were excluded that had the following values: HAZ <−6 or >6 or WHZ <−5 or >5
Selective reporting	Low risk of bias	All outcomes that are mentioned in the introduction, abstract and or methods section are also reported in the result section.
Conflict of interest	Low risk of bias	Study funded by the Feed the Future Innovation Lab for Small-Scale Irrigation (ILSSI), led by Texas A&M University. There were associations with other research projects. People from University are involved in data collection.

Table S14. Risk of bias summary for W. Tesfaye et al., 2022

Domain	Assessment	Reasoning
Selection strategy	Probably low risk of bias	Recruitment strategy is not specified. Sampling is not described in detail. The authors mentioned that unobserved house hold characteristics can lead to selection bias which can influence the level of crop diversification. The latter issue is however solved by using fixed effects instrumental variables (FE-IV) method and by using average neighborhood values.
Blinding of the outcome measurement	Probably low risk of bias	No specific blinding strategies have been described, However, survey data was used as part of the LMSMS-ISA project of the world bank. Secondary data.
Exposure assessment	Probably low risk of bias	Drought shock defined as children living in areas that experience drought. Further climate data that is provided is temp and rainfall data. Mean rainfall and max temp between 2001 and 2015. Details about drought shocks not further specified.
Confounding	Probably high risk of bias	There is controlled for household characteristics, but not for the analyses between crop diversification and malnutrition.
Outcome data	Low risk of bias	Malnutrition metrics against the WHO standards. Wasting and stunting. Clear Z-score cut-off values are used.
Selective reporting	Low risk of bias	All outcomes that are mentioned in the abstract introduction and or method section are also mentioned in the results section.
Conflict of interest	Low risk of bias	Funding is received from the African Economic Research Consortium (AERC).

Table S15. Risk of bias summary for A. de Waal et al., 2006

Domain	Assessment	Reasoning
Selection strategy	Low risk of bias	It is mentioned that sites were randomly selected. That was consistent for the two data sources. Districts were selected based on whether they have faced drought episodes. Two samples, one sample with both drought affected and non drought affected areas and rural and urban sites. One sample with only drought affected rural sites.
Blinding of the outcome measurement	Probably low risk of bias	No specific blinding strategies have been described, However, an ongoing panel into socio-economic well-being was used. Numerous sources of bias in the data collection phase are mentioned, meaning that authors are aware of risks.
Exposure assessment	Probably low risk of bias	The UN World Food Program (WFP) indicated whether areas were drought-affected or not. WFP assumed to be a trustworthy and transparent organization. However, it is unclear what cut-off values are for the outcome.
Confounding	Not applicable	Single cross-sectional study that only investigated prevalence of malnutrition in drought and non-drought affected areas. No relations are studied.
Outcome data	Probably high risk of bias	Indirect measures (amongst other backward extrapolation techniques) are used to estimate child mortality. Participants were asked to recall mortality in the last 3 years.
Selective reporting	Probably low risk of bias	All outcomes that are mentioned in the abstract, introduction and or methods section are also mentioned in the results section. However, in the results section, stunting metrics were also briefly mentioned while this was not touched upon in the intro/abstract or method section.
Conflict of interest	Low risk of bias	Funding by UNICEF. Survey data obtained from research institutes.

Table S16. Risk of bias summary for S. Hagos et al., 2014

Domain	Assessment	Reasoning
Selection strategy	Probably low risk of bias	Recruitment strategy not described. It is assumed that administrative zones are equally divided and that DHS data is equally divided over the zones. Otherwise selection bias could have been introduced. > half of the administrative zones from Ethiopia are included, indicating that it is representative.
Blinding of the outcome measurement	Probably low risk of bias	No specific blinding strategies have been described. However, outcome data from the Ethiopia Socioeconomic survey was used and it is assumed that this procedure did not introduce bias. data is used that already existed.
Exposure assessment	Probably low risk of bias	Rainfall measured by weather stations is generally considered a source that is not introducing bias due to the lack of human interference. Variabilities can still be present. Both linear and quadratic terms were used for rainfall, meaning that multiple values for rainfall are explored. No cut-off or threshold values are identified.
Confounding	Probably high risk of bias	Only controlled for livelihoods.
Outcome data	Low risk of bias	Standard malnutrition metrics are used against the WHO guidelines. Clear cut-off values are mentioned: <2SD moderate malnutrition and <3SD severe malnutrition.
Selective reporting	Low risk of bias	All outcomes mentioned in the abstract title introduction and method section were also mentioned in the results section.
Conflict of interest	Low risk of bias	It is declared that there is not conflict of interest in this study.

Table S17. Risk of bias summary for P. Salama et al., 2001

Domain	Assessment	Reasoning
Recruitment strategy	Probably low risk of bias	Recruitment not described. Sampling method was described. Sample size calculation was provided.
Blinding of the outcome measurement	Probably low risk of bias	No specific blinding strategies were mentioned. However, house hold surveys were used to collect anthropogenic data. Therefore, researchers were not directly involved in the data collection and therefore the risk of bias was minimized. Mortality data was collected retrospectively.
Exposure assessment	Probably low risk of bias	The world food program acknowledged the presence of a real drought induced presence in 1999-2000. No further details.
Confounding	Not applicable	Cross-sectional study. Prevalence is provided. No associations investigated.
Outcome data	Probably low risk of bias	Regarding weight measurements, there was referred to the Salter scales Model MP 25. No information about cut-off values.
Selective reporting	Low risk of bias	All outcomes that are reported in the abstract, introduction or method section are also reported in the results section.
Conflict of interest	Unclear	No specific statements about collaborations or funding.