BMJ Paediatrics Open

The impact of climate change on child nutrition in Indonesia: a conceptual framework and scoping review of the available evidence

David Colozza ,[1] Isabella Guo,[1,2] Sri Wahyuni Sukotjo,[1] Astrid Citra Padmita,[1] Rene Gerard Galera,[3] Endang Sulastri,[4] Inti Wikanestri,[4] Mamadou Ndiaye[1]

To cite: Colozza D, Guo I, Sukotjo SW, *et al*. The impact of climate change on child nutrition in Indonesia: a conceptual framework and scoping review of the available evidence. *BMJ Paediatrics Open* 2025;**9**:e002980. doi:10.1136/bmjpo-2024-002980

► Additional supplemental material is published online only. To view, please visit the journal online (https://doi.org/10.1136/bmjpo-2024-002980).

Received 23 August 2024
Accepted 13 February 2025

[1]UNICEF Indonesia, Jakarta, Indonesia
[2]Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland, USA
[3]UNICEF East Asia and Pacific Regional Office, Bangkok, Thailand
[4]Ministry of National Development Planning, Jakarta, Indonesia

Correspondence to
Dr David Colozza; dcolozza@unicef.org

ABSTRACT

Background Climate change is expected to significantly impact child nutrition, worsening global health inequities. Indonesia, a country highly vulnerable to climate change, also faces substantial child malnutrition challenges. However, comprehensive knowledge on climate change's impacts on child nutrition in Indonesia is limited. This study addresses this gap through a scoping review of the scientific evidence on the effects of climate change on child nutrition in Indonesia.

Methods We developed a conceptual framework based on global literature to guide our systematic search, linking climate change to child nutrition and its determinants in Indonesia. Systematic searches were conducted in English and Indonesian on Scopus, Web of Science and PubMed, supplemented by Google Scholar and citation screening. We included peer-reviewed, Scopus-indexed studies focused on Indonesia, examining either direct or indirect impacts of climate change on child nutrition. A narrative synthesis was performed, structured around outcomes identified in our framework: (1) nutrition-associated conditions, (2) diets and disease, (3) social dynamics and (4) food system shocks.

Results From 3025 records, 134 studies met the inclusion criteria. Studies were either multicountry including Indonesia (23%, n=31), Indonesia-specific across multiple regions (26%, n=35) or region-specific, mainly focused on Java (22%, n=29), Sumatra (11%, n=14), Kalimantan (7%, n=9) and Sulawesi (7%, n=9). Other regions were underrepresented (5%, n=7). Most studies used quantitative methods (87%, n=116). Few studies assessed direct links between climate change and nutritional outcomes (n=5), food security or dietary quality (n=7); more focused on indirect pathways such as disease (n=49), social dynamics (n=18) and food system disruptions (n=55).

Conclusions Evidence suggests significant impacts of climate change on child nutrition in Indonesia, highlighting the need for urgent action. Further localised studies that consider contextual factors, and actions focused on strengthening health and nutrition systems, are critical, especially in regions most vulnerable to both climate change and child malnutrition.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Climate change impacts child nutrition through multiple pathways.
⇒ Indonesia is highly vulnerable to climate change and child malnutrition.

WHAT THIS STUDY ADDS

⇒ A synthesis of evidence on climate change's impacts on child malnutrition in Indonesia.
⇒ A framework to assess climate change's impacts on child nutrition in other regions.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Climate change undermines child nutrition in Indonesia, highlighting the urgent need to climate-proof policies, local food and health systems.

INTRODUCTION

Child malnutrition remains a pressing concern in Indonesia. Child stunting and wasting persist at alarming rates[1]; meanwhile, overweight, obesity and non-communicable diseases (NCDs) are on the rise,[2] making Indonesia one of the largest nations grappling with a triple burden of malnutrition.[3] Food insecurity also remains concerning, with up to 14.5% of households affected in the most disadvantaged provinces.[4] Poor diets are widespread among Indonesian children. Only 60% of children aged 6–23 months achieve minimum dietary diversity,[5] and less than 40% consume a minimum acceptable diet,[6] while over 95% of school-age children and adolescents do not meet the recommended daily fruit and vegetable intake.[2]

Climate change is expected to further exacerbate these challenges, putting millions of people at increased risk of malnutrition and food insecurity,[7] further amplifying existing global health inequities.[8] Estimates for Indonesia indicate uncertain rainfall pattern shifts, owing to the diverse topographies and climates across the country's 17 500 islands; however, they consistently predict warming

temperature trends, under both business-as-usual and mitigation scenarios.[9] Moreover, Indonesia ranks high among countries at risk of climate-related disasters, including floods, cyclones, sea-level rise, droughts and heatwaves. A growing number of people, particularly vulnerable populations, including children, are expected to suffer from these hazards and the related rise in malnutrition and food insecurity.[9]

Despite the growing evidence of the negative impacts of climate change on child malnutrition,[10 11] a comprehensive understanding of the scientific evidence available for Indonesia is lacking. This review seeks to fill this critical knowledge gap, by addressing two questions: (1) what is the current state of the scientific knowledge regarding climate change's impacts on child nutrition in Indonesia? and (2) what are the main evidence gaps in terms of impact pathways, and of geographical disparities across the country?

METHODS

Search strategy and selection criteria

We searched Scopus, Web of Science and PubMed to conduct a scoping review of the literature on climate change impacts on child nutrition in Indonesia. Due to the expected scarcity of country-specific evidence, we also searched Google Scholar and screened citations from the articles included in the review. Searches were conducted on 10 July 2023 and again on 20 December 2023 to capture any relevant studies published in the meantime.

We included studies examining either the direct impact of climate change—such as altered rainfall patterns, rising temperatures and extreme weather events—on nutrition-associated conditions, or its indirect impact through underlying determinants: diets, food security, non-diet-related diseases, socioeconomic shocks and food system disruptions. The theoretical framework underlying the search strategy, analysis and presentation of results (figure 1) was developed based on the global literature on climate change and nutrition,[8 12–16] and on existing food security and nutrition frameworks.[17 18]

We included studies focused on Indonesia (or its subregions) and multicountry studies that provided disaggregated findings for Indonesia. Searches were conducted in both English and Indonesian, with no restrictions on year or methodology. For quality assurance, only peer-reviewed studies published in Scopus-indexed journals were included. We excluded articles that did not examine the effect of climate change on relevant

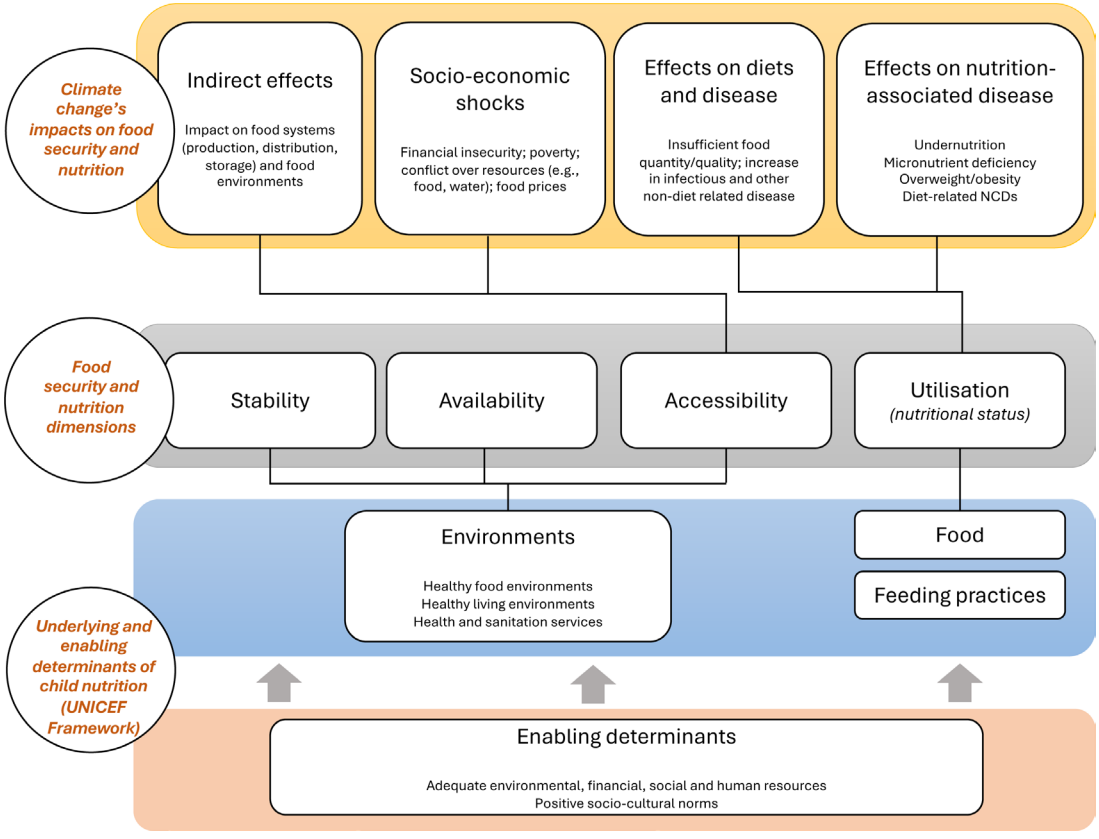

Figure 1 Theoretical framework highlighting the impacts of climate change on food security and nutrition. Climate change impacts nutritional status (the utilisation dimension of food security) directly, via increased risk of nutrition-associated disease, and indirectly, via negative effects on diets and on other communicable and non-diet-related disease (corresponding to the 'food' and 'feeding practices' underlying determinants in the UNICEF framework). Additionally, climate change affects nutritional status indirectly, via socio-economic shocks and disruptions to food systems (the 'environment' underlying determinant in the UNICEF framework), that threaten the accessibility, availability and stability dimensions of food security.

nutrition outcomes or underlying determinants (eg, studies on changing rainfall patterns without links to the implications for food production or livelihoods), those focused on climate change adaptation or mitigation, laboratory experiments, policy/legal reviews, conference proceedings and opinion pieces. The full search strategy is detailed in the online supplemental materials. Two reviewers (DC and IG) assessed independently articles retrieved against the set inclusion criteria. Discrepancies were resolved through multiple rounds of discussion between the two coders. Results are reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses for Scoping Reviews guidelines.

Data analysis

We exported results to JabRef (V.5.8) for initial data cleaning and duplicate removal, then transferred them to a predesigned MS Excel (V.16.7) form, capturing source, title, authors, journal, year, full citation and abstract. After screening records against inclusion criteria, we added further details to the shortlisted articles for coding: geographic scope, exposure (climate change component), outcome (nutrition or underlying determinant), methods and link to the theoretical framework. Given the review's scoping nature, and the consequent diverse focus and methodology of included studies, a meta-analysis was not feasible. Instead, we provide a narrative synthesis organised across the outcomes outlined in our framework: (1) nutrition-associated conditions, (2) diets and disease, (3) social dynamics and (4) food systems shocks.

Patient and public involvement

No patient involved.

RESULTS

Descriptive characteristics of the studies included

We retrieved 3025 records for screening based on the inclusion criteria. After removing 657 duplicates and 557 records using automated tools (eg, conference papers and abstracts), 1811 records remained for eligibility assessment based on title and abstract, resulting in 136 records for full-text screening. Of these, 18 studies were excluded, 14 were added through citation searching, and 2 more from searches conducted in December 2023, totalling 134 studies included in the review (figure 2).

Selected articles span the period 1999–2023 and show a growing trend over time, with about half (49%, n=66) published between 2020 and 2023, and about one-third (32%, n=43) between 2015 and 2019. Half of the studies are multicountry studies also including Indonesia (23%, n=31) or Indonesia-specific studies covering multiple regions (26%, n=35). The remaining studies are region-specific, and mostly focus on Java (22%, n=29), followed by Sumatra (11%, n=14), Kalimantan (7%, n=9) and Sulawesi (7%, n=9), with fewer on East/West Nusa Tenggara, Bali (2 each) and Papua (1). Most studies use quantitative methods (87%, n=116).

Regarding exposure, most studies (72%, n=96) examine climate variables, with 62% (n=83) assessing multiple variables, and others focusing on temperature (7%, n=9) and rainfall (3%, n=4). Extreme events like droughts, floods, tsunamis, landslides and fires are the second most studied (14%, n=18), while two studies each cover sea-level rise and coral bleaching. The remaining studies (13%, n=17) assess combined climate, environmental and socioeconomic factors.

Analysis of findings

Direct impacts on nutrition-related diseases

Evidence directly linking climate change with nutrition-associated conditions in Indonesia is limited, with only five of the 134 studies focusing on this connection. Two studies suggest a significant negative impact of delayed monsoon onset and lack of rainfall on child height,[19] stunting and wasting.[20] This is explained as primarily the effect of decreased agricultural yields, which reduce availability and access to diverse, nutritious foods during drier seasons, impacting child nutrition. Another study examined the effects of a 1998 climate-induced coral bleaching event, finding that children exposed to the event were more likely (29.6%) to be severely stunted than their peers 2 years later, and to fail a grade in school by 2007.[21] This was attributed, among others, to income shocks and reduced food availability from marine ecosystem degradation, leading to decreased dietary protein intake.

The remaining two studies projected future impacts of climate change on all forms of malnutrition[16] and diet-related NCDs.[22] By 2050, Indonesia could face a substantial increase in climate-induced deaths due to underweight (+14.7%), despite a parallel decrease in overweight-related deaths. Additionally, climate-related deaths per capita could rise to an estimated 35 per million (95% CI 6.6, 64.1), primarily due to reduced fruit and vegetable consumption.[16] Future projections also suggest that increased days with temperatures above 30°C could significantly impact diet-related NCDs,[22] with increases in primary healthcare visits for diabetes (25%), cardiovascular disease (14%) and all causes (8%) from 2060 to 2080, along with an estimated additional annual financial burden of US$ 25 million (IDR 336 billion) from primary healthcare costs under a high-emission scenario.[22]

Indirect impacts through diets and disease

Several studies (n=56) examined climate change's impacts on nutrition via two closely related pathways, food security and dietary quality and via non-diet-related diseases.

Diets

Studies on the link between climate change, food security and dietary quality (n=7) overall highlight negative impacts. A study using longitudinal data from 13 provinces suggests that climate shocks such as delays in

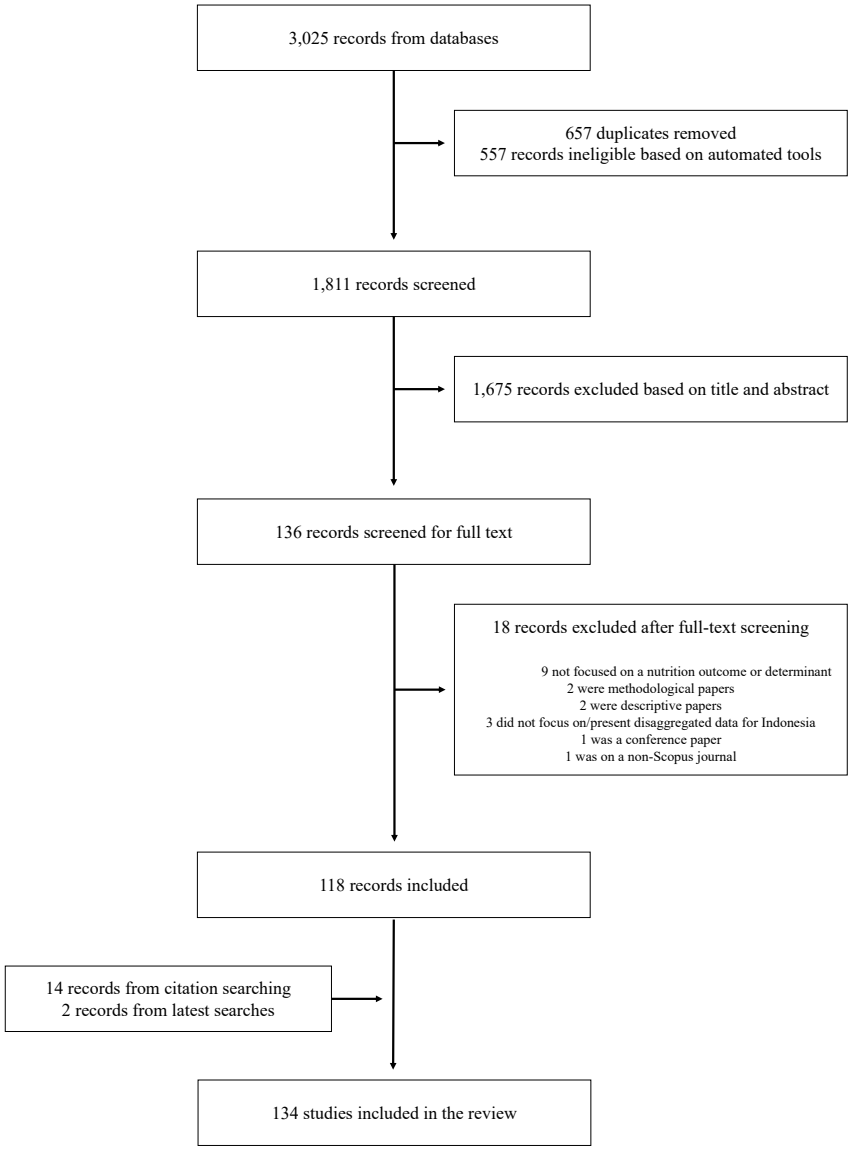

Figure 2 PRISMA flowchart of records retrieval and selection based on inclusion criteria. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

monsoon onset and higher temperatures led households to skip meals, substitute nutritious foods for less nutritious alternatives or allocate higher household budget shares to food expenditures.[23] Similarly, studies conducted in Central Sulawesi province show that drought events led 85% of the farm households surveyed to reduce food expenditures by up to −64%. This resulted in significant declines in both the quality and quantity of foods consumed, with 30% of the households forced to eat less than three meals per day, and all of them reducing consumption of protein-rich foods such as fish and meat.[24]

Evidence from the provinces of East Nusa Tenggara,[25] Central and East Java and Yogyakarta[26] also suggests severe impacts from climate change and climate-induced extreme events such as drought and floods across multiple food security dimensions. These include impacts on availability, with reduced crop yields and livestock production, accessibility, with negative effects on farmers' income, and utilisation, with increased occurrence of infectious disease. A study on the effects of coral bleaching on fisheries-reliant communities across 13 provinces also found a decline in dietary quality, resulting from lower household consumption of protein-rich foods due to reduced incomes.[27]

Other studies offer qualitative evidence on the impacts of climate change on food security. Research among children aged 10–17 shows that those residing in rural areas

reported several perceived threats to their food security and nutritional status, including increased crop failure risk due to drought and water scarcity, migration of their parents and flooding events affecting their houses.[28] Meanwhile, a study in Central Sulawesi found significant food security impacts among local coastal communities, with increased coastal erosion and adverse weather conditions reducing availability and access to local indigenous food resources due to limited physical access to fishing and hunting grounds or increased time needed to collect food.[29]

Disease

A large number of studies (n=49) examined the impact of climate change on communicable and non-diet-related diseases that affect nutrition and food security. These conditions can increase child malnutrition risk through direct effects (eg, diarrhoea limiting nutrient absorption) and indirect effects (eg, reduced appetite and socioeconomic shocks like income loss due to illness). Studies focused on the relationship between climate variables (rainfall, temperature, humidity) or extreme events (floods, droughts, fires) and health conditions suggest significant potential negative impacts.[30]

Several studies explored vector-borne diseases such as dengue/dengue haemorrhagic fever (DHF), malaria and chikungunya. Research consistently shows positive correlations between higher temperatures, rainfall and humidity with increased DHF risk.[31–54] However, studies reveal a high degree of heterogeneity, suggesting a nuanced role of local climate conditions.[33–35 51 55 56] For example, a lack of precipitation in typically high-rainfall areas may heighten DHF risk by creating mosquito breeding grounds, while extreme rainfall might reduce incidence by washing out these grounds. Conversely, in drier areas, high rainfall can increase breeding grounds, while a lack of precipitation might eliminate them. Only one study suggested that lower night temperatures might increase DHF risk, potentially due to increased outdoor activity during cooler nights.[52] Future projections of climate change suggest varying impacts on dengue mosquito suitability across Indonesia, with potential increases in Java, Bali, East and West Nusa Tenggara, Sulawesi and inland Papua and declines in parts of Sumatra, Kalimantan and Papua from 2030.[38 55]

Evidence on malaria also suggests an overall positive association with higher temperatures and increased disease risk,[56–60] but more mixed patterns of association with precipitation.[58 59] Studies estimating future projections suggest possible suitability increase for malaria across most of the country, based on expected climatic changes between 2050 and 2100[60]; however, the lack of localised climate data limits the possibility to provide accurate estimates, considering the importance of local factors in explaining the association.[57] The only study focused on chikungunya found instead weak and mixed patterns of association, attributed to a strong effect of unobserved local climate variables in explaining the association.[61]

Other studies focused on diarrhoea, showing mixed patterns of association between climate variables and increased disease risk.[62–65] However, some offer evidence of increased future risk due to the broader impacts of climate change on extreme weather events, such as flooding, which can increase transmission risk[63] and water and sanitation systems.[65] A study looking at multiple waterborne diseases came to similar conclusions, suggesting increased future risk due to higher likelihood of floods under Representative Concentration Pathway 4.5 precipitation scenario, estimating a twofold increase in infected people in the study locations (Medan and Surabaya).[66] Two studies focused on the association between climate variables and COVID-19, finding weak and mixed links, likely due to strong confounding from other socioeconomic and environmental variables.[67 68]

Studies looking at heat-related stress also found significant negative impact from climate change on workers' health—particularly those working outdoors, who are exposed to dangerous temperatures for longer.[69] Projections of future heat stress risk also suggest a possible substantial increase in mortality among older people, with an estimated 12–15 times increase in the 2050s compared with the 2010s,[70] and a possible increase in all-cause mortality in deforested areas due to increased temperatures.[71] Other studies focused on climate change impact on respiratory diseases. One study found that changes in rainfall patterns and land cover, leading to increased occurrence of fires and air pollution, resulted over the past 20 years in a substantial increase in respiratory illnesses (+8.5% during dry years).[72] Similarly, others found a strong link between drought-induced fire and air pollution with increased respiratory illness risk, premature death and livelihood impacts via workdays lost.[55 73 74]

Finally, two studies looked at the impacts of extreme events (specifically landslides) on mental health.[75 76] Findings show both short and long-term impacts in affected populations, due to damage to infrastructure and farmland, as well as loss of social and family networks and connections, with severe effects particularly among those who were displaced after the event and those who were living in more precarious housing. Two studies provided qualitative evidence on the perceived effects of climate change across multiple health conditions among 200 respondents in Semarang, Central Java[77] and of perceived impacts related specifically to dengue among 400 respondents located in Jakarta.[78] Findings highlight how most respondents were aware and had experienced climate change (including changing weather patterns, increased temperatures and higher frequency of extreme events) and perceived potential health impacts in terms of increased disease risk.

Indirect impacts through social dynamics

Other studies (n=18) examined climate-induced socioeconomic shocks that negatively impact child nutrition by reducing the quantity, quality and affordability of food, threatening child care and feeding practices and disrupting access to essential nutrition services. Most studies used multi-indicator indexes to assess various socioeconomic and well-being dimensions, consistently finding adverse effects of climate change on livelihoods in Indonesia through multiple pathways. Communities reliant on agriculture and fisheries are particularly vulnerable, with climate change and extreme events damaging agricultural productivity[79–85] and negatively impacting fish stocks and fishing practices, for example, due to increased weather unpredictability,[86 87] reduced food availability and employment opportunities,[80 88] increased conflict over water resources,[79] decreased wages and higher household expenditures, including for food.[83 89] Macrolevel studies also highlighted negative impacts on fisheries,[90 91] tourism and leisure services[91] and increased rice prices,[92] alongside increased violence resulting from declining food availability, increased prices,[93] water insecurity[94] and increased poverty.[95] Marginalised communities are disproportionately affected,[96] with one study showing that individuals most vulnerable to floods were less likely to relocate to safer areas postevent.[97]

Indirect impacts through food systems shocks

Another subset of studies (n=55) examined the impact of climate change on child nutrition through disruptions in food systems, focusing on crop production, fisheries or both. Most studies on crop production assessed how climate variables and extreme events affect crop yields, finding significant potential for negative impacts due to increased climate variability and anomalies that directly damage crops and indirectly threaten production.

Many studies focused on rice, suggesting potential negative effects from higher temperatures, delayed monsoon onset, reduced precipitation,[98–113] extreme rainfall events,[114] drought[115–120] and floods,[116 121] leading to direct crop damage, reduced suitable growing areas and suboptimal crop growth conditions. While some studies suggest possible yield benefits from higher CO2 levels[122 123] and expanded suitable growing areas,[101] these may be outweighed by the negative impacts described earlier.[101] Additionally, one study noted indirect impacts on rice production due to increased heat stress risk for workers.[124]

Changing temperatures and rainfall patterns are expected to reduce suitable growing areas for crops like coffee[125–128] and oil palm, with projections indicating up to a 47% decline nationwide by 2050,[129] and significant reductions in key regions, for example, Kalimantan[130] and Sumatra.[131] While expansion to new regions could partially offset these suitability declines, it could also lead to increased deforestation.[128 129] Similar trends are observed for eucalyptus,[132] cashew[133] and avocado,[133] with reduced suitability due to higher temperatures or wetter conditions.

Several studies highlighted increased crop damage risk from higher climatic suitability for pests and diseases, leading to more frequent outbreaks. Affected crops include rice,[134] oil palm,[135–137] eucalyptus,[132] cocoa,[138] mango[139] and rubber tree, with mixed associations between temperature and disease type.[140 141] Potato blight risk was instead negatively associated with increased temperatures, although with minimal effect size.[142] One study noted potential negative impacts on crop wild relatives—an essential resource to ensure future resilience of essential crops and protect communities against food insecurity and malnutrition—predicting significant decreases in their distribution range by 2080, although none is expected to go extinct.[143]

Qualitative evidence suggested heightened perceptions of climate change's widespread impacts on Indonesia's agricultural systems. Rice farmers in Sumatra cited climate change, particularly floods, as a major factor in rice crop failures.[144] In Kalimantan, many local rubber farmers reported medium (48%) or high (27.5%) impacts on yields from climate change, including increased rainfall and altered timing. Factors such as increased rainfall quantity, altered timing and extended duration negatively affect their farming activities.[145] Similar concerns were raised by vegetable farmers in Java, who noted more frequent pest and disease outbreaks and reduced crop yields.[146] Beekeepers across multiple provinces also identified climate-related factors as a significant cause of bee mortality in their operations.[147]

A small subset of studies focused on climate change impacts on fisheries, forecasting significant disruptions. Indonesia was identified as one of the countries with the largest projected decline in fisheries productivity, up to −20% in maximum catch potential.[148] Other studies raised urgent concerns about climate-related damage to local fisheries, with one study ranking Indonesia as the most vulnerable among 27 countries to coral reef fisheries damage,[149] and another estimating declines in catch potential of −15.9% on average, and up to −32% in specific sites.[150] These findings highlight significant food security concerns. Given that many Indonesian communities depend on fisheries rather than agriculture, potential gains from climate-induced agricultural improvements (eg, increased CO2 fertilisation) may not compensate for losses in the fisheries sector.[150] Subregional studies also identified climate-induced changes in season timing as a threat to local ecosystems. For example, projected temperature increases in Sulawesi were found to threaten coral reefs and alter species distributions, impacting local aquaculture productivity,[151] while climate-induced changes in Java marine ecosystems were projected to reduce tuna fisheries productivity.[152 153]

DISCUSSION

We conducted a scoping review of the available scientific evidence on climate change's impact on child nutrition in Indonesia, identifying 134 relevant articles. Although direct estimates of impacts on nutritional outcomes are limited (n=5), the data show significant negative associations between climate variables, undernutrition, food security and dietary quality. Delayed monsoon onset and rising temperatures were linked to reduced crop yields and decreased access to nutritious diets,[19 20] while climate-induced coral bleaching affected the availability and affordability of foods from marine ecosystems.[21 27] Future projections also indicate potential mortality increases due to climate-induced underweight, NCDs and reduced fruit and vegetable consumption.[16 22] These findings align with global evidence showing negative links between climate change, child undernutrition and food security.[10 154] However, no study addressed climate change's impact on obesity risk, such as through the substitution of healthy foods with unhealthy ultraprocessed foods. While establishing a direct causal link remains challenging, the evidence suggests potentially significant negative impacts on nutrition in Indonesia, especially given the country's high rates of child undernutrition, food insecurity and the rising burden of obesity and NCDs.[3]

A larger number of studies highlight the ongoing and projected impacts of climate change on the underlying determinants of child nutrition, via non-diet-related disease, socioeconomic shocks and food system disruptions. In line with global evidence, changing climatic variables are expected to impact future climatic suitability and transmission risk for diseases like dengue,[31–54] malaria[56–60] and diarrhoea,[62–65] although estimates carry substantial uncertainties.[155–157] Higher temperatures, wildfires, air pollution and climate-induced extreme events can also increase risk of heat-related stress,[69–71] respiratory diseases[72–74] and mental disorders.[75 76] These issues not only harm individual health directly but can also lead to income loss and worsened living conditions, thereby affecting child nutrition indirectly. Indonesia's high vulnerability to fires,[158] pollution and environmental challenges,[159] and lack of mental healthcare services[160] will likely aggravate these effects.

Findings also suggest that climate change can significantly impact child nutrition indirectly, through socioeconomic shocks that undermine availability and access to adequate food and care practices. Within communities, data suggest widespread harm to livelihoods, through damage to agricultural production and fisheries,[79–88] increased conflict risk,[79 93] declining incomes[83 89] and increased labour needs, with potentially significant impacts on children's nutritional health, childcare and feeding practices, and essential nutrition services. Nationally, evidence suggests substantial economic losses in the agriculture, fishery and tourism sectors[90–92] and impacts on food prices,[92 93] poverty[95] and other socioeconomic indicators. Evidence also suggests that these impacts will disproportionately affect communities that are already marginalised,[96 97] for example, due to socioeconomic status or geography, highlighting how, in Indonesia, climate change will likely widen further existing health inequities.[8]

A last set of studies focused on the impacts of climate change on food systems. Research on food system disruptions focuses primarily on production—most frequently of rice,[98 100–124] but also other crops like coffee[125–128] and oil palm[129–131 135–137]—suggesting substantial direct and indirect damage (eg, from increased pest and disease outbreak frequency) and consequent heightened malnutrition risk. Studies on fisheries similarly predict productivity declines,[148–153] with significant nutrition implications given the reliance of many Indonesian communities on the sector. Overall, our findings align with global evidence showing that climate change is having severe impacts on food systems, and in turn on child health and nutrition.[11 30]

While our study was guided by a robust theoretical framework and systematic literature search, it has some limitations. First, as a scoping review, coverage may not be exhaustive. Although our search strategy retrieved all studies linking climate change directly with nutritional outcomes, it may not have fully captured evidence on underlying determinants. Additional reviews focused on specific determinants (eg, agricultural production, livelihood shocks, health services, childcare practices) could provide a more comprehensive understanding. Second, our tailored theoretical framework helped us synthesise results across categories relevant to policymakers and practitioners. However, given the interconnected nature of child nutrition determinants (eg, crop production impacts can affect simultaneously food availability, income and other socioeconomic variables), categorising climate impacts by primary outcome may have overshadowed other relevant findings. We believe this does not affect the validity of the results, as our goal was to provide an overview of available evidence rather than exhaustively cover each pathway. Finally, the heterogeneity among studies precluded a uniform synthesis, necessitating a narrative presentation.

Despite these limitations, this study provides valuable evidence to guide future interventions addressing climate change and child malnutrition in Indonesia. Although direct evidence linking climate change to nutritional outcomes is limited, data indicate significant negative effects. We identify several knowledge gaps that, if addressed, could inform the design of evidence-based policies and programmes. First, there is a critical gap in understanding the direct link between climate change and nutritional outcomes in Indonesia. Few studies analyse these factors as primary outcomes, limiting our ability to effectively address these challenges. Additionally, robust longitudinal evidence is scarce—most studies rely on cross-sectional data, which fails to capture the gradual nature of both climate change and certain

nutrition-related conditions (eg, NCDs). Furthermore, while there is more evidence on the impact of climate change on food production, other aspects of the food system, such as supply chains, distribution, storage, and waste, remain understudied.

Finally, while data highlight the key role of localised climatic variables in mediating climate change's impacts on child nutrition, subnational evidence remains scarce. Half of the reviewed studies focus on large geographical scales, either as part of multicountry or multiregion studies on Indonesia. Localised evidence is particularly scarce outside Java, Sumatra and Sulawesi, which account for only 5% of the studies reviewed. This lack of localised data limits significantly the generation of robust estimates and projections needed for evidence-based interventions. This is especially concerning for regions like Papua and East Nusa Tenggara, which are particularly vulnerable to compounded risks from malnutrition, climate change and socioeconomic challenges.

Acknowledgements The authors wish to thank Roland Kupka (UNICEF) for his review and comments on a previous version of this article.

Contributors DC led the conceptualisation of the study and methodology, the collection and analysis of data, and the drafting of the manuscript and is the guarantor for the study. IG contributed to the collection and analysis of data and the review of the manuscript. SWS contributed to the conceptualisation of the study and the review of the manuscript. ACP, RGG, ES, IW and MN reviewed and provided input to the manuscript. All authors reviewed and approved the final version of the manuscript prior to publication.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval Not applicable.

Provenance and peer review Part of a Topic Collection; Not commissioned; externally peer-reviewed.

Data availability statement Data sharing not applicable as no datasets generated and/or analysed for this study.

Author note DC, SWS, ACP, RGG and MN are UNICEF staff members. The opinions and statements in this article are those of the authors and may not reflect official UNICEF policies.

ORCID iD

David Colozza http://orcid.org/0000-0002-9065-7537

REFERENCES

1 Ministry of Health - RI. Indonesia health survey (survei kesehatan Indonesia, SKI) 2023. 2024.
2 UNICEF. Landscape Analysis of Overweight and Obesity in Indonesia. 2022:45.
3 Popkin BM, Corvalan C, Grummer-Strawn LM. Dynamics of the double burden of malnutrition and the changing nutrition reality. *Lancet* 2020;395:65–74.
4 Badan Pusat Statistik (BPS) - RI. Population prevalence with moderate or severe food insecurity, based on the scale of food insecurity experience (percent), 2020-2022. 2022.
5 BPS. Health statistics profile (profil statistik kesehatan) 2023. Jakarta, 2023.
6 Ministry of Health - RI. Indonesia health survey (survei kesehatan Indonesia, SKI) 2023. Unpublished data - forthcoming. 2024.
7 Swinburn BA, Kraak VI, Allender S, *et al*. The Global Syndemic of Obesity, Undernutrition, and Climate Change: The Lancet Commission report. *The Lancet* 2019;393:791–846.
8 Romanello M, Napoli C di, Green C, *et al*. The 2023 report of the Lancet Countdown on health and climate change: the imperative for a health-centred response in a world facing irreversible harms. *The Lancet* 2023;402:2346–94.
9 The World Bank Group, Asian Development Bank. Indonesia climate risk country profile. 2021. Available: www.worldbank.org
10 Phalkey RK, Aranda-Jan C, Marx S, *et al*. Systematic review of current efforts to quantify the impacts of climate change on undernutrition. *Proc Natl Acad Sci U S A* 2015;112:E4522–9.
11 Agostoni C, Baglioni M, La Vecchia A, *et al*. Interlinkages between Climate Change and Food Systems: The Impact on Child Malnutrition-Narrative Review. *Nutrients* 2023;15:416.
12 Fanzo J, Davis C, McLaren R, *et al*. The effect of climate change across food systems: Implications for nutrition outcomes. *Glob Food Sec* 2018;18:12–9.
13 Willett W, Rockström J, Loken B, *et al*. Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. *The Lancet* 2019;393:447–92.
14 Romanello M, Di Napoli C, Drummond P, *et al*. The 2022 report of the Lancet Countdown on health and climate change: health at the mercy of fossil fuels. *The Lancet* 2022;400:1619–54.
15 Clark MA, Springmann M, Hill J, *et al*. Multiple health and environmental impacts of foods. *Proc Natl Acad Sci USA* 2019;116:23357–62.
16 Springmann M, Mason-D'Croz D, Robinson S, *et al*. Global and regional health effects of future food production under climate change: a modelling study. *The Lancet* 2016;387:1937–46.
17 UNICEF. Nutrition, for every child UNICEF nutrition strategy 2020–2030. UNICEF publications; 2020.1–98.
18 FAO. Food security. Policy brief. Rome. 2006.
19 Cornwell K, Inder B. Child Health and Rainfall in Early Life. *J Dev Stud* 2015;51:865–80.
20 Thiede BC, Gray C. Climate exposures and child undernutrition: Evidence from Indonesia. *Soc Sci Med* 2020;265:113298.
21 Chaijaroen P. Tradeoffs between fertility and child development attributes: evidence from coral bleaching in Indonesia. *Envir Dev Econ* 2022;27:295–315.
22 Fritz M. Temperature and non-communicable diseases: Evidence from Indonesia's primary health care system. *Health Econ* 2022;31:2445–64.
23 Sellers S, Gray C. Climate Shocks Constrain Human Fertility in Indonesia. *World Dev* 2019;117:357–69.
24 Keil A, Zeller M, Wida A, *et al*. What determines farmers' resilience towards ENSO-related drought? An empirical assessment in Central Sulawesi, Indonesia. *Clim Change* 2008;86:291–307.
25 Balde BS, Setiawati MD, Nampa IW, *et al*. Impacts of climate variability on food security dimensions in Indonesia. In: *Sustainable agriculture systems and technologies*. 2022: 81–116.
26 Rosalia ACTSuryantoSHakim L. Spatial Analysis of the Impact of Flood and Drought on Food Security Index. *NEPT* 2021;20:721–7.
27 Chaijaroen P. Long-lasting income shocks and adaptations: Evidence from coral bleaching in Indonesia. *J Dev Econ* 2019;136:119–36.
28 Lawler J, Patel M. Exploring children's vulnerability to climate change and their role in advancing climate change adaptation in East Asia and the Pacific. *Environ Dev* 2012;3:123–36.
29 Ferguson CE, Marie Green K, Switzer Swanson S. Indigenous food sovereignty is constrained by "time imperialism". *Geoforum* 2022;133:20–31.
30 Rocque RJ, Beaudoin C, Ndjaboue R, *et al*. Health effects of climate change: an overview of systematic reviews. *BMJ Open* 2021;11:e046333.

31 Amelinda YS, Wulandari RA, Asyary A. The effects of climate factors, population density, and vector density on the incidence of dengue hemorrhagic fever in South Jakarta Administrative City 2016-2020: an ecological study. *Acta Biomed* 2022;93:e2022323.
32 Arcari P, Tapper N. The variable impact of ENSO events on regional dengue/DHF in Indonesia. *Singap J Trop Geogr* 2017;38:5–24.
33 Arcari P, Tapper N, Pfueller S. Regional variability in relationships between climate and dengue/DHF in Indonesia. *Singap J Trop Geogr* 2007;28:251–72.
34 Astuti EP, Dhewantara PW, Prasetyowati H, *et al*. Paediatric dengue infection in Cirebon, Indonesia: a temporal and spatial analysis of notified dengue incidence to inform surveillance. *Parasit Vectors* 2019;12:186.
35 Aswi A, Cramb S, Duncan E, *et al*. Climate variability and dengue fever in Makassar, Indonesia: Bayesian spatio-temporal modelling. *Spat Spatiotemporal Epidemiol* 2020;33:100335.
36 Bangs MJ, Larasati RP, Corwin AL, *et al*. Climatic factors associated with epidemic dengue in Palembang, Indonesia: implications of short-term meteorological events on virus transmission. *Southeast Asian J Trop Med Public Health* 2006;37:1103–16.
37 Corwin' AL, Larasati' RP, Bangs' MJ, *et al*. Epidemic dengue transmission in Southern Sumatra, Indonesia. 2001.
38 Davis C, Murphy AK, Bambrick H, *et al*. A regional suitable conditions index to forecast the impact of climate change on dengue vectorial capacity. *Environ Res* 2021;195:110849.
39 Faridah L, Suroso DSA, Fitriyanto MS, *et al*. Optimal Validated Multi-Factorial Climate Change Risk Assessment for Adaptation Planning and Evaluation of Infectious Disease: A Case Study of Dengue Hemorrhagic Fever in Indonesia. *Trop Med Infect Dis* 2022;7:172.
40 Haryanto B. Health adaptation scenario and dengue fever vulnerability assessment in Indonesia. In: *Advances in Asian Human-Environmental Research*. Springer International Publishing, 2016: 221–36.
41 Husnina Z, Clements ACA, Wangdi K. Forest cover and climate as potential drivers for dengue fever in Sumatra and Kalimantan 2006-2016: a spatiotemporal analysis. *Trop Med Int Health* 2019;24:888–98.
42 Kesetyaningsih TW, Andarini S, Sudarto S, *et al*. DETERMINATION OF ENVIRONMENTAL FACTORS AFFECTING DENGUE INCIDENCE IN SLEMAN DISTRICT, YOGYAKARTA, INDONESIA. *AJID* 2018;12:13–35.
43 Kesetyaningsih TW, Andarini S, Sudarto S, *et al*. The minimum-maximum weather temperature difference effect on dengue incidence in sleman regency of Yogyakarta, Indonesia. 2018. Available: http://wjst.wu.ac.th
44 Dimjati Lusno MF, Yudhastuti R, Haksama S, *et al*. Integration of climate, transmission, and spread of dengue hemorrhagic fever in endemic areas. *J Public Health Afr* 2023;14:5.
45 Maulana MR, Yudhastuti R, Lusno MFD, *et al*. Climate and visitors as the influencing factors of dengue fever in Badung District of Bali, Indonesia. *Int J Environ Health Res* 2023;33:924–35.
46 Nuraini N, Fauzi IS, Fakhruddin M, *et al*. Climate-based dengue model in Semarang, Indonesia: Predictions and descriptive analysis. *Infect Dis Model* 2021;6:598–611.
47 Nurjanah S, Atmowidi T, Hadi UK, *et al*. Distribution modelling of Aedes aegypti in three dengue-endemic areas in Sumatera, Indonesia. *Trop Biomed* 2022;39:373–83.
48 Pimpi L, Indratno SW, Puspita JW, *et al*. Stochastic and Deterministic Dynamic Model of Dengue Transmission Based on Dengue Incidence Data and Climate Factors in Bandung City. *CBMS* 2022;5:78–89.
49 Prasetyowati H, Dhewantara PW, Hendri J, *et al*. Geographical heterogeneity and socio-ecological risk profiles of dengue in Jakarta, Indonesia. *Geospat Health* 2021;16.
50 Rosvita NA, Kania N, Suhartono E, *et al*. Spatial-temporal distribution of dengue in Banjarmasin, Indonesia from 2016 to 2020. *IJPHS* 2022;11:1167.
51 Tosepu R, Tantrakarnapa K, Worakhunpiset S, *et al*. Climatic factors influencing dengue hemorrhagic fever in Kolaka district, Indonesia. *Environ Nat Resour J* 2018;16:1–10.
52 Wijayanti SPM, Porphyre T, Chase-Topping M, *et al*. The Importance of Socio-Economic Versus Environmental Risk Factors for Reported Dengue Cases in Java, Indonesia. *PLoS Negl Trop Dis* 2016;10:e0004964.
53 Tosepu R, Tantrakarnapa K, Nakhapakorn K, *et al*. Climate variability and dengue hemorrhagic fever in Southeast Sulawesi Province, Indonesia. *Environ Sci Pollut Res Int* 2018;25:14944–52.
54 Sutriyawan A, Martini M, Sutiningsih D, *et al*. Climatic variations and the incidence of dengue fever in Bandung, Indonesia. *J Public Hlth Dev* 2023;21:222–31.
55 Anyamba A, Chretien J-P, Small J, *et al*. Developing global climate anomalies suggest potential disease risks for 2006-2007. *Int J Health Geogr* 2006;5:60.
56 Marina R, Ariati J, Anwar A, *et al*. Climate and vector-borne diseases in Indonesia: a systematic literature review and critical appraisal of evidence. *Int J Biometeorol* 2023;67:1–28.
57 Hasyim H, Nursafingi A, Haque U, *et al*. Spatial modelling of malaria cases associated with environmental factors in South Sumatra, Indonesia. *Malar J* 2018;17:87.
58 Rejeki DSS, Nurhayati N, Aji B, *et al*. A Time Series Analysis: Weather Factors, Human Migration and Malaria Cases in Endemic Area of Purworejo, Indonesia, 2005-2014. *Iran J Public Health* 2018;47:499–509.
59 Wang C, Thakuri B, Roy AK, *et al*. Changes in the associations between malaria incidence and climatic factors across malaria endemic countries in Africa and Asia-Pacific region. *J Environ Manage* 2023;331:117264.
60 Khormi HM, Kumar L. Future malaria spatial pattern based on the potential global warming impact in South and Southeast Asia. *Geospat Health* 2016;11:290–8.
61 Harapan H, Michie A, Yufika A, *et al*. Effects of El Niño Southern Oscillation and Dipole Mode Index on Chikungunya Infection in Indonesia. *Trop Med Infect Dis* 2020;5:119.
62 Dharmayanti I, Tjandrarini DH, Hidayangsih PS. Climatic factors and childhood diarrhea in South Kalimantan in 2017-2020. *Southeast Asian J Trop Med Public Health* 2022;53:65–80.
63 Fukushi K. Health risk assessment for planning of a resilient city in the changing regional environment. In: *Health in Ecological Perspectives in the Anthropocene*. 2018: 109–15.
64 Prasetyo D, Ermaya Y, Martiza I, *et al*. Correlation between climate variations and rotavirus diarrhea in under-five children in Bandung. *Asian Pac J Trop Dis* 2015;5:908–11.
65 Wibawa BSS, Maharani AT, Andhikaputra G, *et al*. Effects of Ambient Temperature, Relative Humidity, and Precipitation on Diarrhea Incidence in Surabaya. *Int J Environ Res Public Health* 2023;20:2313.
66 Setiawati MD, Jarzebski MP, Miura F, *et al*. The public health risks of waterborne pathogen exposure under a climate change scenario in Indonesia. In: *Springer Climate*. 2022: 607–24.
67 R. A, Santi Martini SM, Lilis Sulistyorini LS, *et al*. Association between Climatic Conditions, Population Density and COVID-19 in Indonesia. *JSM* 2021;50:879–87.
68 Wirasatriya A, Lazuardi L, Wibowo A, *et al*. Transformer-based Deep Learning for COVID-19 Prediction Based on Climate Variables in Indonesia. *Int J Adv Sci Eng Inf Technol* 2023;13:632–7.
69 Masuda YJ, Castro B, Aggraeni I, *et al*. How are healthy, working populations affected by increasing temperatures in the tropics? Implications for climate change adaptation policies. *Glob Environ Change* 2019;56:29–40.
70 Varquez ACG, Darmanto NS, Honda Y, *et al*. Future increase in elderly heat-related mortality of a rapidly growing Asian megacity. *Sci Rep* 2020;10:9304.
71 Wolff NH, Zeppetello LRV, Parsons LA, *et al*. The effect of deforestation and climate change on all-cause mortality and unsafe work conditions due to heat exposure in Berau, Indonesia: a modelling study. *Lancet Planet Health* 2021;5:e882–92.
72 Santika T, Muhidin S, Budiharta S, *et al*. Deterioration of respiratory health following changes to land cover and climate in Indonesia. *One Earth* 2023;6:290–302.
73 Uda SK, Hein L, Atmoko D. Assessing the health impacts of peatland fires: a case study for Central Kalimantan, Indonesia. *Environ Sci Pollut Res Int* 2019;26:31315–27.
74 Hein L, Spadaro JV, Ostro B, *et al*. The health impacts of Indonesian peatland fires. *Environ Health* 2022;21:62.
75 Burrows K, Pelupessy DC, Khoshnood K, *et al*. Environmental Displacement and Mental Well-Being in Banjarnegara, Indonesia. *Environ Health Perspect* 2021;129:117002.
76 Burrows K, Desai MU, Pelupessy DC, *et al*. Mental wellbeing following landslides and residential displacement in Indonesia. *SSM - Mental Health* 2021;1:100016.
77 van de Haterd J, Budiyono B, Darundiati YH, *et al*. Environmental change and health risks in coastal Semarang, Indonesia: importance of local indigenous knowledge for strengthening adaptation policies. *Cities Health* 2021;5:276–88.
78 Coughlan de Perez E, Nerlander L, Monasso F, *et al*. Managing health risks in a changing climate: Red Cross operations in East Africa and Southeast Asia. *Clim Dev* 2015;7:197–207.

79 Salman D, Yassi A, Demmallino EB, *et al*. Livelihood vulnerability of smallholder farmers to climate change: A comparative analysis based on irrigation access in South Sulawesi, Indonesia. *Regional Sustainability* 2022;3:244–53.
80 Boissière M, Locatelli B, Sheil D, *et al*. Local Perceptions of Climate Variability and Change in Tropical Forests of Papua, Indonesia. *E&S* 2013;18.
81 Murniati K, Mutolib A. The impact of climate change on the household food security of upland rice farmers in Sidomulyo, Lampung Province, Indonesia. *Biodiversitas* 2020;21:3487–93.
82 Murniati K, Mulyo JH, Hartono S. The livelihood vulnerability to climate change of two different farmer communities in tanggamus region, lampung province, Indonesia.
83 Salafsky N. Drought in the rain forest: Effects of the 1991 El Nino-Southern Oscillation event on a rural economy in West Kalimantan, Indonesia. *Clim Change* 1994;27:373–96.
84 Suryanto S, Rahman A. Application of livelihood vulnerability index to assess risks for farmers in the Sukoharjo Regency and Klaten Regency, Indonesia. *Jamba* 2019;11:739.
85 Fedele G, Desrianti F, Gangga A, *et al*. Ecosystem-based strategies for community resilience to climate variability in Indonesia. In: *Advances in Natural and Technological Hazards Research*. Netherlands: Springer, 2016: 529–52.
86 Husni A, Nissa ZNA, Trialfhianty TI, *et al*. Vulnerability and Livelihood Adaptation Strategies of Small Island Fishers under Environmental Change: A Case Study of the Barrang Caddi, Spermonde Islands, Indonesia. *JMIC* 2022;11:158–76.
87 Mulyasari G, Waluyati LR, Suryantini A. Livelihood vulnerability to climate change of fishermen in the coastal area of bengkulu province, Indonesia 1. 2020. Available: http://www.bioflux.com.ro/aacl
88 Griffin C, Ellis D, Beavis S, *et al*. Coastal resources, livelihoods and the 2004 Indian Ocean tsunami in Aceh, Indonesia. *Ocean Coast Manag* 2013;71:176–86.
89 Skoufias E, Katayama RS, Essama-Nssah B. Too little too late: welfare impacts of rainfall shocks in rural Indonesia. *Bull Indones Econ Stud* 2012;48:351–68.
90 Nong D. Potential economic impacts of global wild catch fishery decline in Southeast Asia and South America. *Econ Anal Policy* 2019;62:213–26.
91 Mehvar S, Dastgheib A, Filatova T, *et al*. A practical framework of quantifying climate change-driven environmental losses (QuantiCEL) in coastal areas in developing countries. *Environ Sci Policy* 2019;101:302–10.
92 Putra AW, Supriatna J, Koestoer RH, *et al*. Differences in Local Rice Price Volatility, Climate, and Macroeconomic Determinants in the Indonesian Market. *Sustainability* 2021;13:4465.
93 Caruso R, Petrarca I, Ricciuti R. Climate Change, Rice Crops and Violence. Evidence from Indonesia. *SSRN J* 2014.
94 Danielaini TT, Maheshwari B, Hagare D. An assessment of household water insecurity in a rapidly developing coastal metropolitan region of Indonesia. *Sustain Cities Soc* 2019;46:101382.
95 Ahmed SA, Diffenbaugh NS, Hertel TW. Climate volatility deepens poverty vulnerability in developing countries. *Environ Res Lett* 2009;4:034004.
96 Gan CCR, Oktari RS, Nguyen HX, *et al*. A scoping review of climate-related disasters in China, Indonesia and Vietnam: Disasters, health impacts, vulnerable populations and adaptation measures. *Int J Disaster Risk Reduct* 2021;66:102608.
97 Langlois BK, Beaulac L, Berry K, *et al*. Household Flood Severity and Migration Extent in Central Java: Analysis of the Indonesian Family Life Survey. *Int J Environ Res Public Health* 2023;20:5706.
98 Amien I, Rejekiningrum P, Pramudia A, *et al*. Effects of Interannual Climate Variability and Climate Change on Rice Yield in Java, Indonesia. 1996.
99 Amien I, Redjekiningrum P, Kartiwa B, *et al*. Simulated rice yields as affected by interannual climate variability and possible climate change in Java. *Clim Res* 1999;12:145–52.
100 Ansari A, Lin YP, Lur HS. Evaluating and Adapting Climate Change Impacts on Rice Production in Indonesia: A Case Study of the Keduang Subwatershed, Central Java. *Environments* 2021;8:117.
101 Khairulbahri M. Analyzing the impacts of climate change on rice supply in West Nusa Tenggara, Indonesia. *Heliyon* 2021;7:e08515.
102 Kinose Y, Masutomi Y, Shiotsu F, *et al*. Impact assessment of climate change on the major rice cultivar Ciherang in Indonesia. *J Agric Meteorol* 2020;76:19–28.
103 Naylor RL, Falcon WP, Rochberg D, *et al*. Using el niño southern oscillation climate data to predict rice production in Indonesia. 2001.
104 Yuliawan T, Handoko I. The Effect of Temperature Rise to Rice Crop Yield in Indonesia uses Shierary Rice Model with Geographical Information System (GIS) Feature. *Procedia Environ Sci* 2016;33:214–20.
105 Takama T. Climate change and food security vulnerability assessment in bali/Indonesia. In: *Non-Traditional Security Challenges in Asia: Approaches and Responses*. 2017: 93–133.
106 Kirono DGC, Tapper NJ. ENSO RAINFALL VARIABILITY AND IMPACTS ON CROP PRODUCTION IN INDONESIA. *Physical Geography* 1999;20:508–19.
107 Naylor RL, Battisti DS, Vimont DJ, *et al*. Assessing risks of climate variability and climate change for Indonesian rice agriculture. *Proc Natl Acad Sci U S A* 2007;104:7752–7.
108 Takama T, Setyani P, Aldrian E. Climate change vulnerability to rice paddy production in bali, Indonesia. In: *Handbook of Climate Change Adaptation*. Berlin, Heidelberg: Springer Berlin Heidelberg, 2015: 1731–57.
109 Naylor R, Falcon W, Wada N, *et al*. USING EL NIÑO-SOUTHERN OSCILLATION CLIMATE DATA TO IMPROVE FOOD POLICY PLANNING IN INDONESIA. *Bull Indones Econ Stud* 2002;38:75–91.
110 Syaukat Y. The impact of climate change on food production and security and its adaptation programs in Indonesia. 2011.
111 Iizumi T, Ramankutty N. Changes in yield variability of major crops for 1981–2010 explained by climate change. *Environ Res Lett* 2016;11:034003.
112 Kirono DGC, Butler JRA, McGregor JL, *et al*. Historical and future seasonal rainfall variability in Nusa Tenggara Barat Province, Indonesia: Implications for the agriculture and water sectors. *Clim Risk Manag* 2016;12:45–58.
113 Falcon WP, Naylor RL, Smith WL, *et al*. Using climate models to improve Indonesian food security. *Bull Indones Econ Stud* 2004;40:355–77.
114 Kawanishi M, Mimura N. Rice farmers' response to climate and socio-economic impacts: a case study in North Sumatra, Indonesia. *J Agric Meteorol* 2013;69:9–22.
115 Surmaini E, Hadi TW, Subagyono K, *et al*. Early detection of drought impact on rice paddies in Indonesia by means of Niño 3.4 index. *Theor Appl Climatol* 2015;121:669–84.
116 Venkatappa M, Sasaki N, Han P, *et al*. Impacts of droughts and floods on croplands and crop production in Southeast Asia - An application of Google Earth Engine. *Sci Total Environ* 2021;795:148829.
117 Keil A, Teufel N, Gunawan D, *et al*. Vulnerability of smallholder farmers to ENSO-related drought in Indonesia. *Clim Res* 2009;38:155–69.
118 Karuniasa M, Pambudi PA. The analysis of the El Niño phenomenon in the East Nusa Tenggara Province, Indonesia. *J Water Land Dev* 2022;52:180–5.
119 Ha TV, Huth J, Bachofer F, *et al*. A Review of Earth Observation-Based Drought Studies in Southeast Asia. *Remote Sens (Basel)* 2022;14:3763.
120 Trisasongko BH, Panuju DR, Harimurti H, *et al*. Rapid Assessment of Agriculture Vulnerability to Drought using GIS. *IJTech* 2016;7:114.
121 Förster H, Sterzel T, Pape CA, *et al*. Sea-level rise in Indonesia: on adaptation priorities in the agricultural sector. *Reg Environ Change* 2011;11:893–904.
122 Matthews RB, Kropff MJ, Horie T, *et al*. Simulating the impact of climate change on rice production in Asia and evaluating options for adaptation. *Agric Syst* 1997;54:399–425.
123 Kumar P, Sahu NC, Kumar S, *et al*. Impact of climate change on cereal production: evidence from lower-middle-income countries. *Environ Sci Pollut Res Int* 2021;28:51597–611.
124 Simpson C, Hosking JS, Mitchell D, *et al*. Regional disparities and seasonal differences in climate risk to rice labour. *Environ Res Lett* 2021;16:124004.
125 Bacsi Z, Fekete-Farkas M, Ma'ruf MI. Coffee Yield Stability as a Factor of Food Security. *Foods* 2022;11:3036.
126 Boer R, Jadmiko SD, Hidayat P, *et al*. Managing climate risk in a major coffee-growing region of Indonesia. In: *Global Climate Change and Environmental Policy Agriculture Perspectives*. 2020: 147–205.
127 Sarvina Y, June T, Hadi Sutjahjo S, *et al*. The impacts of climate variability on coffee yield in five indonesian coffee production centers. *CS* 2021;16:1–9.
128 Schroth G, Läderach P, Blackburn Cuero DS, *et al*. Winner or loser of climate change? A modeling study of current and future climatic suitability of Arabica coffee in Indonesia. *Reg Environ Change* 2015;15:1473–82.

129 Paterson RRM, Kumar L, Shabani F, *et al*. World climate suitability projections to 2050 and 2100 for growing oil palm. *J Agric Sci* 2017;155:689–702.
130 Paterson RRM. Oil palm survival under climate change in Kalimantan and alternative SE Asian palm oil countries with future basal stem rot assessments. *For Pathol* 2020;50:50.
131 Paterson RRM. Ganoderma boninense Disease of Oil Palm to Significantly Reduce Production After 2050 in Sumatra if Projected Climate Change Occurs. *Microorganisms* 2019;7:24.
132 Booth TH, Jovanovic T, Arnold RJ. Planting domains under climate change for *Eucalyptus pellita* and *Eucalyptus urograndis* in parts of China and South East Asia. *Aust For* 2017;80:1–9.
133 Grüter R, Trachsel T, Laube P, *et al*. Expected global suitability of coffee, cashew and avocado due to climate change. *PLoS ONE* 2022;17:e0261976.
134 Sopialena S, Palupi PJ. Study of climatic factors on the population dynamics of Pyricularia oryzae on some varieties of paddy rice (Oryza sativa). *Biodiversitas* 2017;18:701–8.
135 Paterson RRM. Future scenarios for Fusarium wilt disease and mortality of oil palm in Nigeria, Ghana and Cameroon, extrapolated to Malaysia and Indonesia. *Eur J Plant Pathol* 2022;162:105–17.
136 Paterson RRM. Future scenarios for oil palm mortality and infection by Phytophthora palmivora in Colombia, Ecuador and Brazil, extrapolated to Malaysia and Indonesia. *Phytoparasitica* 2020;48:513–23.
137 Paterson R. Depletion of indonesian oil palm plantations implied from modeling oil palm mortality and ganoderma boninense rot under future climate. *AIMS Environ Sci* 2020;7:366–79.
138 Bryceson SR, Morgan JW, McMahon PJ, *et al*. A sudden and widespread change in symptoms and incidence of vascular streak dieback of cocoa (Theobroma cacao) linked to environmental change in Sulawesi, Indonesia. *Agric Ecosyst Environ* 2023;350:108466.
139 Galdino T da S, Kumar S, Oliveira LSS, *et al*. Mapping Global Potential Risk of Mango Sudden Decline Disease Caused by Ceratocystis fimbriata. *PLoS ONE* 2016;11:e0159450.
140 Azizan FA, Astuti IS, Young A, *et al*. Rubber leaf fall phenomenon linked to increased temperature. *Agric Ecosyst Environ* 2023;352:108531.
141 Syahfari H, Ramayana AS, Suhaimi A, *et al*. Identification of Climate Influence on Upas Fungus (Corticium sp.) Disease Intensity on Rubber Plants (Hevea brasiliensis Muell.Arg.). *Ujar* 2023;11:146–57.
142 Sparks AH, Forbes GA, Hijmans RJ, *et al*. Climate change may have limited effect on global risk of potato late blight. *Glob Chang Biol* 2014;20:3621–31.
143 Rahman W, Magos Brehm J, Maxted N. The impact of climate change on the future distribution of priority crop wild relatives in Indonesia and implications for conservation planning. *J Nat Conserv* 2023;73:126368.
144 Heŕiansyah P, Anwar P, Pŕima A. Understanding Farmer Perception and Impact of Seasonal Climate Event on Rice Farming in Indonesia: Implication for Adaptation Policy in Local Level. *Yüzüncü Yıl Üniversitesi Tarım Bilimleri Dergisi* 2022;32:462–76.
145 Imelda I, Mulyo JH, Suryantini A, *et al*. Understanding farmers' risk perception and attitude: A case study of rubber farming in West Kalimantan, Indonesia. *AIMS Agriculture and Food* 2023;8:164–86.
146 Irham I, Fachrista IA, Masyhuri M, *et al*. Climate Change Adaptation Strategies by Indonesian Vegetable Farmers: Comparative Study of Organic and Conventional Farmers. *ScientificWorldJournal* 2022;2022:3590769.
147 Buchori D, Rizali A, Priawandiputra W, *et al*. Beekeeping and Managed Bee Diversity in Indonesia: Perspective and Preference of Beekeepers. *Diversity (Basel)* 2022;14:52.
148 Cheung WWL, Lam VWY, Sarmiento JL, *et al*. Large-scale redistribution of maximum fisheries catch potential in the global ocean under climate change. *Glob Chang Biol* 2010;16:24–35.
149 Hughes S, Yau A, Max L, *et al*. A framework to assess national level vulnerability from the perspective of food security: The case of coral reef fisheries. *Environ Sci Policy* 2012;23:95–108.
150 Cinner JE, Caldwell IR, Thiault L, *et al*. Potential impacts of climate change on agriculture and fisheries production in 72 tropical coastal communities. *Nat Commun* 2022;13:3530.
151 Kay S, Avillanosa AL, Cheung VV, *et al*. Projected effects of climate change on marine ecosystems in Southeast Asian seas. *Front Mar Sci* 2023;10:10.
152 Syamsuddin M, Saitoh SI, Hirawake T, *et al*. Interannual variation of bigeye tuna (*Thunnus obesus*) hotspots in the eastern Indian Ocean off Java . *Int J Remote Sens* 2016;37:2087–100.
153 Sambah AB, Noor'izzah A, Intyas CA, *et al*. Analysis of the effect of ENSO and IOD on the productivity of yellowfin tuna (Thunnus albacares) in the South Indian Ocean, East Java, Indonesia. *Biodiversitas* 2023;24:2689–700.
154 Myers SS, Smith MR, Guth S, *et al*. Climate Change and Global Food Systems: Potential Impacts on Food Security and Undernutrition. *Annu Rev Public Health* 2017;38:259–77.
155 Naish S, Dale P, Mackenzie JS, *et al*. Climate change and dengue: a critical and systematic review of quantitative modelling approaches. *BMC Infect Dis* 2014;14:167.
156 Caminade C, Kovats S, Rocklov J, *et al*. Impact of climate change on global malaria distribution. *Proc Natl Acad Sci U S A* 2014;111:3286–91.
157 Semenza JC. Cascading risks of waterborne diseases from climate change. *Nat Immunol* 2020;21:484–7.
158 Herawati H, Santoso H. Tropical forest susceptibility to and risk of fire under changing climate: A review of fire nature, policy and institutions in Indonesia. *For Policy Econ* 2011;13:227–33.
159 World Bank Group. Country climate and development report. Indonesia, 2023. Available: https://www.worldbank.org/en/country/indonesia/publication/indonesia-country-climate-and-development-report
160 Hartini N, Fardana NA, Ariana AD, *et al*. Stigma toward people with mental health problems in Indonesia. *Psychol Res Behav Manag* 2018;11:535–41.