

Occupational Heat Stress in Agricultural Workers: A Systematic Review of Physiological, Psychological, and Socioeconomic Impacts Informing Agronursing Practice

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Abstract:

Climate change intensifies extreme heat, disproportionately threatening agricultural workers. The multifaceted impacts of occupational heat stress across physiological, psychological, and socioeconomic domains remain fragmented in current literature. This systematic review synthesizes recent empirical evidence on the impacts of heat stress on global farming populations to inform evidence-based agronursing interventions. A systematic search was conducted across Scopus, PubMed, and ProQuest for studies published in the last three years, adhering to PRISMA 2020 guidelines. Methodological quality was appraised using the Joanna Briggs Institute tools. Twelve studies met the inclusion criteria. Synthesis revealed that extreme heat induces severe physiological strain, notably acute kidney injury, electrolyte depletion, and high prevalence of heat-related symptoms. Psychologically, chronic heat exposure significantly elevates anxiety, depression, and climate-related distress, often exacerbated by restrictive immigration policies. Behaviorally, spontaneous adaptations like self-pacing are insufficient and disproportionately burden female workers. Macroeconomically, declines in heat-induced labor capacity threaten national GDP and exacerbate household welfare disparities in arid regions. Occupational heat stress precipitates cascading health and economic crises among agricultural workers. Agronursing frameworks must urgently integrate continuous physiological monitoring, routine mental health screenings, and gender-responsive occupational policies. Interdisciplinary collaborations are essential for developing localized early warning systems and enforcing stringent thermal risk regulations to safeguard worker well-being and global food security.

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INTRODUCTION

Climate change is intensifying extreme heat exposure globally, posing severe occupational health risks to outdoor agricultural workers whose labor remains critical to agricultural production and global food security (El Khayat et al., 2022). Emerging agronursing perspectives, aligned with broader planetary health frameworks in nursing, increasingly recognize climate-related occupational hazards as interconnected threats to human well-being, agricultural worker health, and the sustainability of food-production systems (Vandenberg et al., 2025; Kurniyawan et al., 2026). Macroeconomic simulations demonstrate that heat stress-induced declines in labor capacity could

reduce national gross domestic product by up to 20 percent under severe warming scenarios (Houessou et al., 2025). High-resolution spatial modeling corroborates that occupational heat stress thresholds are frequently exceeded during key harvest months, placing millions of farmworkers at high risk (Parajuli et al., 2026).

Agricultural workers face disproportionate physiological, psychological, and socioeconomic burdens due to prolonged exposure to extreme temperatures and inadequate workplace protections (Iglesias-Rios et al., 2023). Occupational heat exposure induces substantial thermoregulatory strain, dehydration, electrolyte depletion, and acute organ injury, particularly kidney injury, across diverse agricultural environments worldwide (Abasilim et al., 2024). Field studies demonstrate that heat-induced urinary acidification significantly amplifies inflammatory responses, driving acute declines in renal function among outdoor laborers (Yang et al., 2026). Sweat loss is the primary driver of sodium and potassium depletion, leading to marked interindividual variability in thermophysiological responses among temporary agricultural workers (Cemeli et al., 2026). The prevalence of severe heat-related symptoms increases significantly with each incremental increase in wet-bulb globe temperature among sugarcane harvesters (Van Tongeren et al., 2026). Farmworkers also exhibit an elevated burden of anxiety and depression compared to national benchmarks (Castellano et al., 2026).

Current agronursing and occupational health interventions primarily focus on individual-level behavioral adaptations and basic hydration strategies to mitigate heat strain (Roca et al., 2025). Subsistence farmers use self-pacing, extended work hours, and task shifting to limit physiological strain, yet women exhibit higher physiological strain indices due to concurrent household responsibilities (Eggert et al., 2025). Shifting work hours to avoid peak heat emerges as the most effective farm-level adaptation strategy, potentially reducing modeled productivity losses by up to 40 percent during critical harvest months (Ferro et al., 2025). Community-based agronurses often deliver culturally competent education on hydration and on recognizing early symptoms of heat-related illness using indigenous knowledge-based approaches (Nyambe et al., 2025).

Existing literature predominantly examines isolated physiological or macroeconomic outcomes, lacking a comprehensive synthesis of the cascading effects of heat stress across multiple domains within the agronursing framework (Nath et al., 2026). Chronic heat stress substantially lowers life satisfaction among migrant farmworkers, primarily driven by negative physical, cognitive, and emotional health outcomes (Chabba & Bhat, 2025). Extreme heat and concurrent public health crises significantly reduce the average number of hours worked by migrant farmworkers, driven by financial vulnerabilities compelling labor market participation under hazardous conditions (Sánchez-Vargas et al., 2025). The integration of wearable technology provides actionable data for identifying high-risk work shifts, yet comprehensive models linking micro-level physiological strain to macro-level agricultural outcomes remain underdeveloped (Barteit et al., 2025).

This systematic review introduces a novel agronursing perspective by integrating multidimensional health, environmental, and socioeconomic data to evaluate the holistic impact of occupational heat stress on farming populations. The synthesis transcends traditional occupational health boundaries by connecting acute physiological injuries with profound psychological distress and macroeconomic labor disruptions. Agronursing frameworks must adopt this holistic paradigm to address the interconnected physical, emotional, and financial vulnerabilities exacerbated by global warming (Dasgupta et al., 2024; Tang & Ho, 2025). The review uniquely categorizes diverse methodological approaches, ranging from high-resolution regional weather modeling to longitudinal wearable-sensor tracking, thereby providing a comprehensive evidence base for targeted clinical interventions.

The primary objective of this systematic review is to critically appraise and synthesize recent empirical evidence regarding the multifaceted impacts of heat stress on agricultural workers to inform evidence-based agronursing interventions. The analysis evaluates the incidence, risk factors, and occupational impacts of heat stroke and other severe heat-related illnesses among farming populations worldwide (Tran et al., 2026). Examining the efficacy of current behavioral adaptations and environmental monitoring strategies helps identify critical areas where agronursing practice can mitigate thermal risks (Amoadu et al., 2023). The findings will guide the development of targeted occupational health strategies and gender-responsive policies (Nemer et al., 2026).

Immediate agronursing action is required to promote comprehensive and systemic occupational health policies that protect vulnerable farming communities from escalating climate-related health risks while strengthening the resilience and sustainability of agricultural systems (Masuda et al., 2024). The integration of health monitoring, behavioral education, hydration, cooling strategies, and workplace improvements is essential for protecting outdoor agricultural workers from occupational heat strain (Roca et al., 2025). Translating empirical evidence into actionable public health strategies requires interdisciplinary collaboration, locally responsive heat-health warning systems, and strengthened occupational heat-protection measures (Chandra N & Lee, 2025). Future research should prioritize longitudinal study designs and objective physiological and molecular biomarkers to clarify the cumulative and long-term health consequences of occupational heat exposure among agricultural workers (Nath et al., 2026).

METHOD

Study Design and Protocol

This systematic review was conducted in strict accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines. The methodology was designed to evaluate the incidence, risk factors, and occupational impacts of heat stroke among agricultural populations. A comprehensive and reproducible search strategy was implemented to ensure the highest level of academic rigor.

Information Sources and Search Strategy

A systematic literature search was executed across three major electronic databases: PubMed, Scopus, and ProQuest. The search strategy utilized a combination of Medical Subject Headings (MeSH) terms and free-text keywords to maximize sensitivity and specificity. The primary search string incorporated the following core terms: ("farmer" OR "farm worker" OR "agricultural worker") AND ("heat stroke" OR "heatstroke"). The temporal scope of the search was restricted to articles published within the preceding three years to capture the most current epidemiological and occupational health data.

Eligibility Criteria

Strict eligibility criteria ensured the methodological rigor of the selected literature. Included studies comprised original English-language research articles published within the preceding three years that investigated heat stroke or severe heat-related illnesses among farmers and farmworkers. Eligible manuscripts required open-access availability, an active Digital Object Identifier (DOI), and explicit documentation of ethical approval. Excluded materials encompassed duplicates, conference abstracts and presentations, case reports, editorials, expert opinions, and literature reviews lacking primary data. Publications missing an active DOI or formal ethical clearance were disqualified.

Study Selection Process

The study selection process followed a rigorous multi-phase screening approach. All retrieved records were imported into reference management software to identify and remove duplicates. Two independent reviewers screened the titles and abstracts against the predefined eligibility criteria. The full texts of potentially relevant articles were subsequently retrieved and assessed for final inclusion. Any discrepancies between the reviewers were resolved through discussion or by consulting a third independent reviewer. The complete study selection process was documented using a PRISMA 2020 flow diagram.

Quality Assessment and Risk of Bias

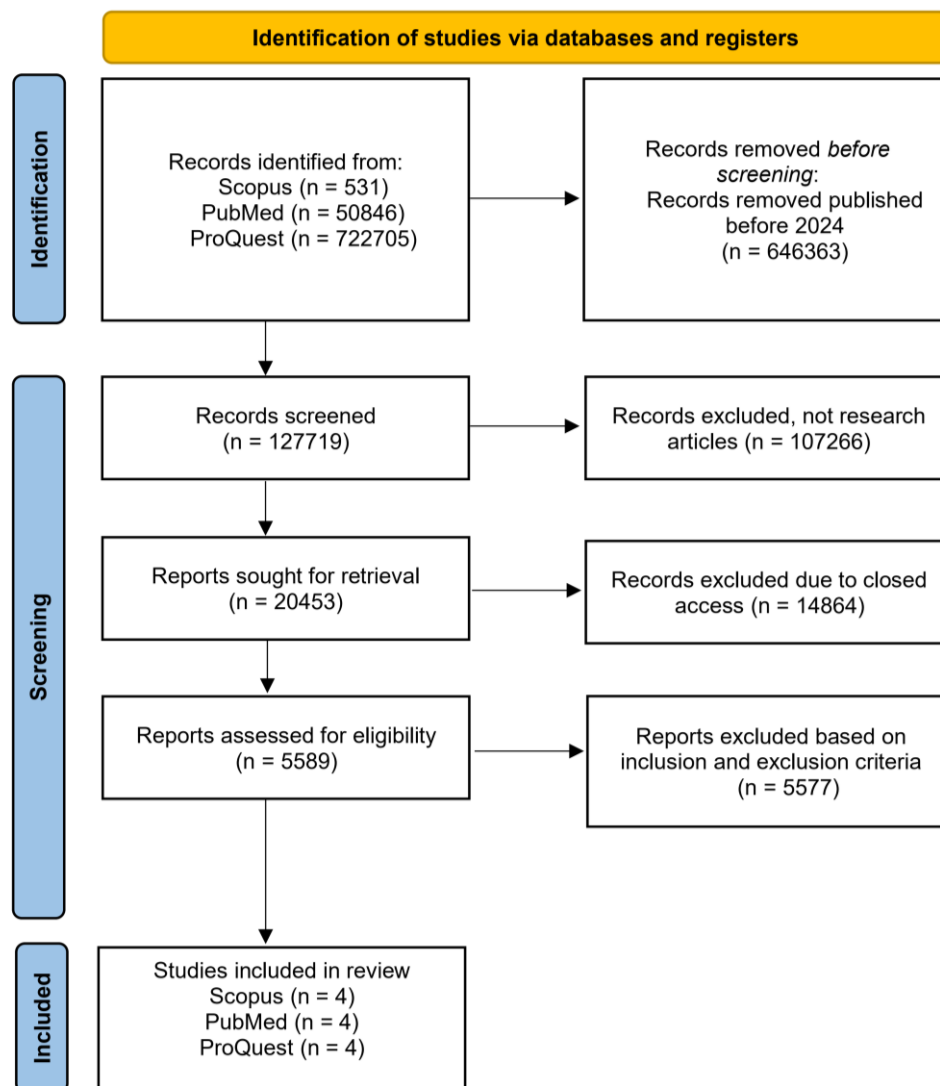
The methodological quality and risk of bias of the included studies were evaluated using the Joanna Briggs Institute (JBI) Critical Appraisal tools. The specific JBI checklist corresponding to each study design (analytical cross-sectional, cohort, quasi-experimental) was applied. Two independent reviewers conducted the quality assessment. The evaluation scrutinized critical domains such as the justification for the sample size, the validity of the exposure measurement, the identification of confounding factors, and the appropriateness of the statistical analysis. Disagreements during the appraisal process were resolved via consensus to ensure the reliability of the quality assessment.

RESULT

The systematic literature search was executed across three major electronic databases: Scopus, PubMed, and ProQuest. This comprehensive search strategy initially yielded a substantial pool of 774,082 records, comprising 531 records from Scopus, 50,846 from PubMed, and 722,705 from ProQuest. A primary temporal filtering step was immediately applied to align with the predefined publication timeframe. This step resulted in the removal of 646,363 records published before 2024. Consequently, 127,719 records remained and advanced to the initial title and abstract screening phase.

During the screening phase, a rigorous evaluation of document types was conducted to ensure methodological relevance. A total of 107,266 records were excluded because they did not constitute original research articles, effectively removing duplicates, conference abstracts, case reports, literature reviews lacking primary data, editorials, and expert opinions. This filtration left 20,453 reports sought for full-text retrieval. Access limitations significantly affected the retrieval process, resulting in the exclusion of 14,864 reports due to closed-access restrictions. Ultimately, 5,589 reports were successfully retrieved and advanced to the full-text eligibility assessment.

The full-text assessment involved a detailed evaluation of the remaining reports against the predefined inclusion and exclusion criteria, which mandated English language, active DOIs, and explicit ethical clearance. This rigorous appraisal resulted in the exclusion of 5,577 reports that failed to meet the specific methodological, thematic, or ethical requirements of the review. Following this comprehensive evaluation, a final total of 12 studies were deemed eligible for inclusion in the systematic review. The included studies were evenly distributed across the searched databases, with four studies originating from Scopus, four from PubMed, and four from ProQuest, ensuring a balanced and robust representation of the available high-quality literature.



Picture 1. PRISMA 2020 flow diagram

Table 1. Results of included studies

Author	Objectives	Study Design	Sample Size (N)	Instrument	Main findings
Eggert et al. 2025. Germany.	Quantify the effect of heat stress on physical effort during agricultural labor. Evaluate self-pacing and behavioral adaptation strategies used by subsistence farmers to mitigate heat stress.	A 12-month, prospective, longitudinal observational cohort study.	Of the 78 participants (39 households) initially recruited, 76 (38 men, 38 women) were included in the analysis.	Wrist-worn accelerometers (GENEActiv) for activity intensity (ENMO) and sleep tracking; miniaturized ECG devices (Faros 180) for heart rate; dual heat-flux headband sensors (Dräger Tcore) for estimated core body temperature; and GPS trackers (G-Porter/Garmi) for	Spontaneous behavioral adaptations (such as pacing and schedule shifts) allow self-employed farmers to limit heat strain. However, these strategies are increasingly inadequate amid worsening climate change, disproportionately strain women, and risk reducing agricultural yields and increasing food insecurity without formal intervention.

Author	Objectives	Study Design	Sample Size (N)	Instrument	Main findings
Nyambe et al. 2025. Zambia.	Assess occupational heat stress risk among rural farmers in two different agro-ecological zones (Monze and Sioma districts) in Zambia.	Cross-sectional pilot study using triangulated data (environmental heat monitoring, cross-sectional questionnaire, and retrospective national health data).	N = 200 small-scale rural farmers (100 from Monze, 100 from Sioma; 92 males, 108 females).	location and field perimeter mapping. Extech® HT30 Wet Bulb Globe Temperature (WBGT) meters for recording environmental parameters. Validated quantitative Heat Stress Risk at the Workplace (HSRW) questionnaire.	Heat stress poses an escalating occupational hazard to smallholder farmers in Zambia. To mitigate these risks, there is an urgent need for localized weather forecasting systems, early workplace warnings, shade structures (traditional insaka), adjusted work schedules, and climate adaptation practices such as agroforestry.
Chabba & Bhat (2025). USA.	To analyze multiple and differential impacts of chronic heat stress (HS) on subjective well-being (SWB) in southern Florida.	Quantitative cross-sectional survey study using an integrated socioeconomic model and a multi-layered SWB model derived from behavioral and health economics.	N = 730 (589 general residents, 141 migrant farmworkers).	Structured survey questionnaire (administered via Qualtrics and face-to-face/phone) measuring daily urban life and heat interference (DUL-HS), work absenteeism/presenteeism (WAP-HS), health outcomes (HO-HS), and subjective well-being (SWB) using Likert scales.	Chronic HS significantly lowers life satisfaction in southern Florida. Daily life HS lowers SWB for general residents, while health-related HS lowers SWB for farmworkers. Authors recommend targeted heat adaptations: water, rest, shade, PPE, healthcare for workers, and efficient cooling + green infrastructure for residents.
Barteit et al. (2025). Burkina Faso and Kenya.	To investigate how environmental heat exposure influences subsistence farmers' physiological and behavioral responses, and how these cascading effects impact agricultural harvest yields and the nutritional status of children under five in their households. It also examines differences in labor performance and recovery between households with and without cool roof coatings.	Prospective cohort study (nested within a larger cluster-randomized controlled trial in the Burkina Faso site).	N = 210 participants (subsistence farmers and children residing in their households) across 25 villages during the feasibility phase.	Environmental: Automated weather stations, iButton DS1923 hygrochrons, SwitchBot sensors, and portable Wet Bulb Globe Temperature (WBGT) devices. Physiological/Behavioral: Wearable devices (Garmin Vivosmart 5, Activinsights GENEActiv Original) for heart rate, activity, and sleep; Renkforce GP-102 GPS trackers for spatial/temporal work patterns.	The study hypothesizes and aims to demonstrate that heat exposure induces physiological stress that reduces farmers' work capacity, leading to decreased harvest yields and poorer nutritional outcomes in children. The integrated data is expected to provide evidence-based insights to inform climate-resilient agricultural policies and heat-adaptation strategies to protect farmer health and ensure food security in vulnerable communities.

Author	Objectives	Study Design	Sample Size (N)	Instrument	Main findings
Castellano et al. (2026). United States (Florida).	To explore cross-sectional associations between heat-related illness (HRI) symptoms and mental health outcomes.	Cross-sectional, exploratory pilot survey study.	N = 53 adult farmworkers.	Patient Health Questionnaire (PHQ-9) for depression, Generalized Anxiety Disorder scale (GAD-7) for anxiety, Climate Change Psychological Distress (CCPD) scale, and an 8-symptom Heat-Related Illness (HRI) checklist.	Florida farmworkers exhibit an elevated burden of anxiety, depression, and climate change psychological distress compared to national benchmarks, particularly among those reporting two or more HRI symptoms. This highlights the urgent need for integrated approaches that combine heat-safety protections, routine mental health screening in community settings, and attention to the policy environments shaping healthcare access.
Van Tongeren et al. (2026); Thailand.	To investigate the effect of heat stress exposure on overall heat-related symptoms and severe heat-related symptoms (those characteristics of heat stroke) among sugarcane workers in Thailand.	Cross-sectional study (data collected at two timepoints: during the cooler and hotter months of the 2023 harvesting period).	N = 295 participants (165 males, 130 females).	Environmental: Wet-Bulb Globe Temperature (WBGT) monitors (QUESTemp 34) to measure full-shift time-weighted average effective heat stress exposure. Self-reported: A structured, validated questionnaire assessing demographics, health behaviors, working conditions, and the occurrence of 21 heat-related symptoms.	Thai sugarcane workers experience a very high prevalence of heat-related symptoms, with 98% reporting at least one symptom and 74% reporting at least one severe symptom. The risk and number of both overall and severe heat-related symptoms increase significantly with every 1°C increase in heat stress exposure (WBGT). These findings highlight an urgent need for targeted policies and protective measures to safeguard sugarcane and other agricultural workers from excessive occupational heat stress.
Yang et al. (2026); Taiwan.	To explore the mechanisms linking occupational heat stress to acute kidney injury (AKI) among agricultural workers, specifically examining physiological strain, renal hemodynamics, urinary biomarkers, and urine acidification.	Pre-post field study with repeated measures.	N = 119 agricultural workers	Heat stress trackers (Kestrel 5400 HST and Kestrel DROP D3). Telemetric capsule system (e-Celsius Performance) for core body temperature and a chest-worn heart rate sensor (Polar H10) to calculate the Physiological Strain Index (PSI). Renal/Kidney Function: Point-of-care serum creatinine analyzer (StatSensor)	Occupational heat stress is associated with acute kidney injury (AKI), driven by elevated core temperature, increased renal vascular resistance (ischemia), proximal tubular injury, and inflammatory activation. Notably, heat-induced urinary acidification was significantly associated with amplified inflammatory responses (elevated MCP-1), highlighting a novel

Author	Objectives	Study Design	Sample Size (N)	Instrument	Main findings
				pre- and post-shift; wireless Doppler ultrasound (ASUS LU700C) to measure the renal artery resistance index (RI).	mechanistic pathway for heat-related kidney injury and underscoring the need for stronger heat-health protections for outdoor workers.
Parajuli et al. (2026). USA (Southern California)	To examine the frequency of heat stress exceedance in the Imperial and Coachella Valleys of southern California using wet bulb globe temperature (WBGT) modeled via the Weather Research and Forecasting (WRF) model, to evaluate how heat exposure varies by work hours, seasons, and crop types, and to propose targeted heat stress mitigation strategies for farmworkers.	High-resolution regional weather modeling and simulation study (using a 1-km resolution WRF model for the reference year 2020).	This is a regional modeling study covering all agricultural areas in the Imperial and Coachella Valleys, representing environmental conditions for approximately 20,000 active farmworkers in the region, rather than a direct survey of human participants.	Weather Research and Forecasting (WRF) model (version 4.4) driven by ERA5 reanalysis data, coupled with the PyWBGT package (Liljegren's method) to calculate effective Wet Bulb Globe Temperature (WBGT _{eff}), and established labor response functions (Kjellstrom's and ISO-LRF) to estimate heat-related productivity loss.	Occupational heat stress thresholds (WBGT > 80°F) are frequently exceeded for hundreds of hours during key harvest months, putting farmworkers at high risk of heat-related illness. Heat risk varies significantly by crop, season, workload, and shift timing. Shifting work hours to early morning or late evening can reduce modeled productivity loss by up to 40%. The findings underscore the urgent need for targeted mitigation strategies, including variable rest-break schedules, avoiding nighttime summer irrigation, using WBGT rather than air temperature for regulatory monitoring, and revising regional heatwave definitions to protect agricultural workers better.
Ferro et al. (2025). Italy.	To evaluate the perceived effectiveness of farm-level adaptation measures aimed at mitigating the adverse impacts of heat waves on agricultural workers' labor productivity, and to understand land managers' assessments of the advantages, disadvantages, and overall effectiveness of these strategies.	Exploratory interviews followed by a cross-sectional survey utilizing the Analytic Hierarchy Process (AHP) for multi-criteria decision analysis.	N = 9 farms (9 fully completed questionnaires from land managers out of 15 initial responses).	A 34-item structured questionnaire administered via QualtricsXM, incorporating pairwise comparison matrices based on Saaty's 1–9 scale (Analytic Hierarchy Process) to evaluate adaptation measures against criteria such as worker acceptability, timeliness of implementation, and flexibility of application.	Heat waves can cause productivity losses of up to 30% among common agricultural workers in the absence of adaptation measures. Shifting or anticipating work hours to avoid peak heat is perceived as the most effective, flexible, and acceptable adaptation strategy, followed by increasing the frequency of breaks with access to potable water. These low-cost, easily implementable measures enhance both worker safety and operational efficiency.

Author	Objectives	Study Design	Sample Size (N)	Instrument	Main findings
Sánchez-Vargas et al. (2025); United States (California).	To examine the separate and combined effects of extreme heat and the COVID-19 pandemic on the probability of migrant farmworkers participating in the agricultural labor market and the average number of hours they work.	Cross-sectional survey study utilizing a two-stage Heckman selection model to correct for self-selection bias in labor market participation.	N = 280 migrant farmworkers.	A structured, tablet-administered survey questionnaire (130 variables) assessing demographics, household characteristics, health conditions, and specific exposures to extreme heat and COVID-19. The Least Absolute Shrinkage and Selection Operator (LASSO) machine learning technique was used for variable selection, followed by Heckman regression modeling to estimate labor supply and participation.	Extreme heat, both alone and in combination with COVID-19, increases the probability of farmworkers choosing to participate in the agricultural labor market (driven by financial vulnerability and self-selection), whereas COVID-19 alone does not. However, once in the labor market, extreme heat, COVID-19, and their combined effect all significantly reduce the average number of hours worked. This underscores the severe vulnerability of farmworkers compelled to work in hazardous conditions due to economic necessity, highlighting the urgent need for comprehensive policies to improve working conditions, healthcare access, and heat protection measures.
Cemeli et al. (2026). Spain.	To analyze the physiological effects of high-temperature exposure by quantifying and correlating indirect indicators of dehydration and electrolyte imbalance (sodium and potassium losses, sweat, body weight, and blood pressure) in temporary agricultural workers.	Observational study with repeated measures over nine consecutive days.	N = 10 temporary agricultural workers (yielding 90 daily observations)	An ad hoc sociodemographic/health questionnaire, a body weight scale, an electronic blood pressure monitor, and a reusable hDrop wearable device for continuous, real-time, non-invasive measurement of skin surface temperature, sweat rate, and sodium/potassium loss, supplemented by local weather station data for ambient conditions.	Sweat loss is the primary driver of electrolyte depletion (sodium and potassium), with marked interindividual variability in thermophysiological responses. Monitoring sweat-related indicators and diastolic blood pressure can help detect the risk of dehydration, highlighting the urgent need for targeted hydration strategies (including electrolyte replacement) and occupational health education to protect vulnerable agricultural workers exposed to extreme heat.
Houessou et al. (2025); Burkina Faso.	To examine the heterogeneous effects of heat stress, via declined labor capacity under +1.5 °C and +3.5 °C global warming	Macroeconomic simulation study using a comparative-static single-country Computable General	N/A (This is a macro-level modeling study based on a nationally representative 2019 Social	A 2019 Social Accounting Matrix (SAM) for Burkina Faso, the STAGE version 2 CGE model, and Wet Bulb Globe Temperature (WBGT)-based labor response	Heat stress-induced labor productivity loss causes significant economic downturns, reducing national GDP by 9% and 20% under +1.5 °C and +3.5 °C warming scenarios, respectively.

Author	Objectives	Study Design	Sample Size (N)	Instrument	Main findings
	scenarios, on agriculture, macroeconomic indicators, and household welfare across three distinct agro-ecological zones (Sudanian, Sudano-Sahelian, and Sahelian) in Burkina Faso.	Equilibrium (CGE) model.	Accounting Matrix encompassing 12 household groups across 3 agro-ecological zones, rather than a direct human participant sample).	functions (ISO and Lancet-LRF) to estimate climate change-induced labor productivity loss.	Outdoors, labor-intensive sectors (e.g., cropping, mining) are the most severely affected. Welfare losses are experienced by all households in the 3.5 °C scenario, with the rural poor and households residing in the Sahelian zone being the most vulnerable. The findings underscore the urgent need for economic diversification, agricultural mechanization, and targeted adaptation policies (e.g., agroforestry, cool roofs, early warning systems) to protect vulnerable populations and sustain food security.

Table 2. Joanna Briggs Institute (JBI) Critical Appraisal Checklist

Author (Year); Country	Study Design	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Overall Quality / Risk of Bias
Eggert et al. (2025); Burkina Faso	Longitudinal observational cohort	Y	Y	Y	Y	Y	Y	Y	Y	High quality. Robust longitudinal design, valid wearable instruments, and appropriate mixed-effects modeling controlling for confounders.
Nyambe et al. (2025); Zambia	Cross-sectional pilot study	Y	Y	Y	Y	Y	Y	Y	Y	High quality. Clear sampling, validated HSRW tool, objective WBGT measures, and appropriate logistic regression.
Chabba & Bhat (2025); USA	Cross-sectional survey	Y	Y	Y	Y	Y	Y	Y	Y	High quality. Large sample, validated SWB constructs, and robust ordered probit analysis controlling for SES.
Barteit et al. (2025); Burkina Faso & Kenya	Study protocol (prospective cohort)	Y	Y	Y	U	Y	Y	Y	U	Moderate (protocol). Sound methodological design planned. Empirical outcomes and statistical validity cannot be fully appraised until data collection is complete.
Castellano et al. (2026); USA	Cross-sectional pilot survey	Y	Y	Y	Y	Y	Y	Y	Y	Moderate–high quality. Validated mental health scales were used. Wide confidence intervals due to the small sample size ($N = 53$) limit precise effect estimation.
Van Tongeren et al. (2026); Thailand	Cross-sectional study	Y	Y	Y	Y	Y	Y	Y	Y	High quality. Rigorous WBGT measurement with clothing adjustment, validated symptom questionnaire, and

Author (Year); Country	Study Design	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Overall Quality / Risk of Bias
										appropriate negative binomial regression.
Yang et al. (2026); Taiwan	Pre-post field study (repeated measures)	Y	Y	Y	Y	Y	Y	Y	Y	High quality. Objective physiological and biomarker measurements, a clear AKI definition, and robust difference-in-differences analysis.
Parajuli et al. (2026); USA	Regional weather modeling study	NA	Y	Y	Y	NA	NA	Y	NA	Moderate (modeling). High-resolution WRF modeling is robust. JBI human-subject criteria (Q1, Q5, Q6, Q8) do not apply to macro-level environmental simulations.
Ferro et al. (2025); Italy	Cross-sectional survey (AHP)	Y	Y	Y	Y	U	Y	Y	Y	Moderate quality. Small sample size ($N = 9$) and a consistency ratio ($CR = 0.20$) exceeding the ideal 0.10 threshold indicate potential cognitive bias in pairwise comparisons.
Sánchez-Vargas et al. (2025); USA	Cross-sectional survey	Y	Y	Y	Y	Y	Y	Y	Y	High quality. Innovative use of LASSO for variable selection and the Heckman two-stage model effectively addresses self-selection bias.
Cemeli et al. (2026); Spain	Observational study (repeated measures)	Y	Y	Y	Y	U	Y	Y	Y	Moderate quality. High-quality wearable technology was used. However, the very small sample size ($N = 10$) limits statistical power and generalizability.
Houessou et al. (2025); Burkina Faso	Macroeconomic simulation (CGE model)	NA	Y	Y	Y	NA	NA	Y	NA	Moderate (modeling). Robust SAM database and CGE modeling. JBI human-subject criteria (Q1, Q5, Q6, Q8) do not apply to macroeconomic simulations.

Note. Y = yes; U = unclear; NA = not applicable; JBI = Joanna Briggs Institute; HSRW = heat stress and related workload; WBGT = wet-bulb globe temperature; SWB = subjective well-being; SES = socioeconomic status; AKI = acute kidney injury; WRF = Weather Research and Forecasting model; AHP = analytic hierarchy process; LASSO = least absolute shrinkage and selection operator; CGE = computable general equilibrium; SAM = social accounting matrix.

JBI Checklist Question Legend:

Code Question

- Q1 Were the criteria for inclusion in the sample clearly defined?
- Q2 Were the study subjects and the setting described in detail?
- Q3 Was the exposure measured validly and reliably?
- Q4 Were objective, standard criteria used for measurement of the condition?
- Q5 Were confounding factors identified?
- Q6 Were strategies to deal with confounding factors stated?
- Q7 Were the outcomes measured validly and reliably?
- Q8 Was an appropriate statistical analysis used?

The critical appraisal of the included studies using the Joanna Briggs Institute (JBI) Critical Appraisal Checklist for Analytical Cross-Sectional Studies. For modeling and simulation studies (Parajuli et al., Houessou et al.) and study protocols (Barteit et al.), certain criteria regarding human subject confounding and statistical analysis of primary data are marked as "Not Applicable (NA)" or

"Unclear (U)", with notes provided in the overall quality assessment. The majority of the primary empirical studies (Eggert et al., Nyambe et al., Chabba & Bhat, Van Tongeren et al., Yang et al., Sánchez-Vargas et al.) demonstrate high methodological quality. These studies utilized objective environmental measures (WBGT), validated physiological or psychological instruments, and advanced statistical techniques (e.g., mixed-effects models, Heckman selection models, DID analysis) to control for confounding variables.

Studies rated as moderate quality (Castellano et al., Ferro et al., Cemeli et al.) are primarily limited by small sample sizes (ranging from N=9 to N=53), which result in wide confidence intervals, reduced statistical power, or higher consistency ratios in decision-making matrices. The study by Barteit et al. is a protocol; therefore, its empirical validity remains pending. Finally, Parajuli et al. and Houessou et al. are modeling studies. While their computational methodologies are robust, the standard JBI clinical appraisal criteria for human-subject confounding and primary statistical analysis do not apply to these macro-level simulations.

Agricultural workers face disproportionate risks from climate change-induced heat stress. Recent literature highlights the multifaceted impacts of extreme temperatures on this vulnerable population. The current systematic review synthesizes findings across physiological, psychological, behavioral, and macroeconomic domains. Studies from diverse geographic contexts reveal a critical need for targeted occupational health interventions to protect outdoor laborers and ensure global food security.

Physiological and Pathophysiological Impacts

Occupational heat exposure triggers severe physiological strain and acute health complications among agricultural laborers. Van Tongeren et al. (2026) documented a remarkably high prevalence of heat-related symptoms among Thai sugarcane workers, noting that 98% of participants experienced at least one symptom and 74% reported severe symptoms characteristic of heat stroke. The severity of these symptoms increases linearly with every 1°C rise in Wet Bulb Globe Temperature (WBGT). Renal vulnerability represents another critical pathophysiological consequence of occupational heat stress. Yang et al. (2026) demonstrated that heat stress induces acute kidney injury (AKI) in Taiwanese farmers through mechanisms involving elevated core temperature, renal ischemia, and urinary acidification. Urinary acidification significantly amplifies inflammatory responses, as evidenced by elevated monocyte chemotactic protein-1 (MCP-1) levels. Electrolyte depletion further exacerbates physiological strain. Cemeli et al. (2026) identified sweat loss as the primary driver of sodium and potassium depletion in temporary agricultural workers in Spain. Monitoring sweat-related indicators and diastolic blood pressure provides a viable method for detecting dehydration risk in real time. Longitudinal physiological monitoring by Eggert et al. 2025 in Burkina Faso confirmed that heat stress significantly elevates the physiological strain index, with women experiencing disproportionately higher strain during fieldwork due to limited pacing strategies.

Psychological and Mental Health Consequences

The psychological burden of heat stress constitutes an underrecognized dimension of occupational health. Chabba & Bhat (2025) established that chronic heat stress significantly diminishes subjective well-being (SWB) in southern Florida. General residents experienced reduced life satisfaction due to heat interference with daily activities. In contrast, farmworkers experienced declines in life satisfaction and in feelings of life's worth, driven by negative physical, cognitive, and emotional health outcomes. The economic toll of heat-related productivity impairment further compounds this psychological distress. Mental health vulnerabilities are intricately linked to both

environmental and policy stressors. Castellano et al. (2026) found that Florida farmworkers exhibit elevated burdens of anxiety, depression, and climate change psychological distress compared to national benchmarks. Participants reporting multiple heat-related illness symptoms demonstrated significantly higher depression scores. Restrictive immigration policies, such as Florida Senate Bill 1718, further deter healthcare-seeking behaviors and exacerbate psychological distress among this demographic.

Behavioral Adaptations and Occupational Interventions

Agricultural workers employ various behavioral adaptations to mitigate heat strain, although these strategies often prove insufficient under worsening climate scenarios. Eggert et al. (2025) observed that subsistence farmers utilize self-pacing, extend working hours, and shift tasks to cooler seasons to limit physiological strain. Women face distinct vulnerabilities in this context, as concurrent household responsibilities restrict their ability to adopt effective pacing strategies. Farm-level adaptation measures require systematic evaluation to ensure optimal implementation. Ferro et al. (2025) utilized the Analytic Hierarchy Process to assess adaptation strategies in Italy, revealing that shifting or anticipating work hours is perceived as the most effective and acceptable intervention. The absence of such adaptations results in productivity losses reaching up to 30%. High-resolution spatial modeling by Parajuli et al. (2026) in southern California corroborates the efficacy of temporal adjustments, demonstrating that shifting work schedules to early- or late-evening hours can reduce modeled productivity loss by up to 40%. Environmental monitoring remains a foundational component of effective adaptation. Nyambe et al. (2025) highlighted that 62.5% of rural farmers in Zambia are at risk of developing heat stress, necessitating the deployment of localized weather forecasting systems and traditional shade structures to mitigate environmental hazards.

Socioeconomic and Macroeconomic Implications

Heat stress induces profound socioeconomic disruptions, affecting individual labor supply and national economic stability. Sánchez-Vargas et al. (2025) analyzed the compounding effects of extreme heat and the COVID-19 pandemic on migrant farmworkers in California. Extreme heat and the dual burden of the pandemic significantly reduce average hours worked. Financial vulnerability forces workers to participate in the agricultural labor market despite hazardous conditions, highlighting a critical failure in occupational safety nets. Macroeconomic simulations illustrate the broader economic ramifications of these labor productivity losses. Houessou et al. (2025) projected that heat stress-induced declines in labor capacity could reduce Burkina Faso's gross domestic product (GDP) by 9% under a +1.5 °C warming scenario and by 20% under a +3.5 °C warming scenario. Outdoors, labor-intensive sectors experience the most severe contractions. Rural poor households and those residing in the Sahelian zone bear the disproportionate brunt of these welfare losses. Comprehensive frameworks are required to link these micro-level health impacts to macro-level agricultural outcomes. Barteit et al. (2025) proposed a prospective cohort design that integrates wearable technology and remote sensing to evaluate how heat exposure cascades from physiological strain among farmers to reduced harvest yields and subsequent child undernutrition.

DISCUSSION

The synthesized findings reveal that occupational heat stress imposes substantial physiological, psychological, and socioeconomic burdens on agricultural workers globally (Tang & Ho, 2025). Extreme environmental temperatures contribute to thermoregulatory strain, dehydration, heat-related illness, and acute kidney injury among agricultural workers across diverse geographical

settings. Agronursing professionals should recognize these multidimensional health threats when developing targeted occupational health strategies for rural farming populations, consistent with broader planetary-health approaches in nursing (Vandenberg et al., 2025). The integration of health monitoring, behavioral education, workplace adaptation, and policy advocacy is therefore essential for strengthening protection against escalating climate-related occupational risks (Tran et al., 2026). Current evidence further indicates that heat and climate-related stressors extend beyond acute physical discomfort, encompassing kidney dysfunction, psychological distress, reduced labor capacity, productivity losses, and wider economic consequences (Dasgupta et al., 2024). Agronursing frameworks should consequently adopt a holistic paradigm addressing the interconnected physical, psychological, socioeconomic, and environmental vulnerabilities intensified by global warming.

Severe physiological strain, particularly acute kidney injury and electrolyte imbalance, represents a critical occupational hazard requiring immediate agronursing assessment. Occupational heat stress drives acute declines in renal function through mechanisms involving elevated core temperatures, renal ischemia, and urinary acidification (Yang et al., 2026). Field studies demonstrate that heat-induced urinary acidification significantly amplifies inflammatory responses, as evidenced by elevated levels of monocyte chemotactic protein-1 and N-acetyl- β -D-glucosaminidase in agricultural workers (Yang et al., 2026). Sweat loss is the primary driver of sodium and potassium depletion, leading to marked interindividual variability in thermophysiological responses among temporary agricultural workers exposed to Mediterranean heat waves (Cemeli et al., 2026). The prevalence of severe heat-related symptoms, including those characteristics of heat stroke, specifically confusion and rapid pulse, increases significantly with every incremental rise in wet bulb globe temperature among sugarcane harvesters (Van Tongeren et al., 2026). Agronursing practitioners must prioritize monitoring renal function, tracking point-of-care biomarkers, and educating on electrolyte replacement to mitigate these life-threatening physiological cascades among outdoor laborers.

The psychological burden of heat exposure, compounded by structural vulnerabilities, significantly degrades the subjective well-being and mental health of farmworkers. Chronic heat stress substantially lowers life satisfaction and feelings of life's worth among migrant farmworkers, primarily driven by negative physical, cognitive, and emotional health outcomes (Chabba & Bhat, 2025). Farmworkers exhibit an elevated burden of anxiety, depression, and climate change psychological distress compared to national benchmarks, with symptom severity directly correlating with the number of heat-related illnesses experienced during single work shifts (Castellano et al., 2026). Restrictive immigration policies further deter healthcare-seeking behaviors and exacerbate psychological distress within these marginalized communities, creating a compounding effect of environmental and systemic stressors (Castellano et al., 2026). Agronursing frameworks must incorporate routine mental health screenings utilizing validated tools to address the invisible psychological toll of climate-driven occupational hazards. Community-based agronurses are uniquely positioned to provide trauma-informed care that acknowledges the intersection of extreme weather and immigration-related anxieties.

Spontaneous behavioral adaptations to heat stress are frequently inadequate and disproportionately burden female agricultural workers in subsistence farming communities. Subsistence farmers use self-pacing, extended work hours, and task shifting to limit physiological strain, yet women exhibit higher physiological strain indices due to concurrent household responsibilities (Eggert et al., 2025). Shifting work hours to avoid peak heat emerges as the most effective and acceptable farm-level adaptation strategy, potentially reducing modeled productivity losses by up to 40% during critical harvest months (Ferro et al., 2025; Parajuli et al., 2026). Women

often lack the autonomy to implement these pacing strategies, forcing them to labor during peak afternoon heat and increasing their vulnerability to severe heat-related morbidity (Eggert et al., 2025). Agronursing interventions must advocate for gender-responsive occupational policies that recognize the dual burdens carried by female farmworkers and promote equitable access to cooling resources. Educational programs designed by agronurses must specifically target the unique thermoregulatory and social challenges faced by women in rural agricultural settings.

Heat-induced declines in labor capacity trigger cascading macroeconomic disruptions and exacerbate household welfare disparities across distinct agro-ecological zones. Extreme heat and concurrent public health crises significantly reduce the average number of hours worked by migrant farmworkers, driven by financial vulnerabilities that compel them to participate in the labor market under hazardous conditions (Sánchez-Vargas et al., 2025). Macroeconomic simulations demonstrate that heat stress-induced labor productivity losses can reduce national gross domestic product by up to 20% under severe warming scenarios, disproportionately devastating rural poor households in arid regions (Houessou et al., 2025). These economic shocks threaten local food security and limit the financial resources available for household health investments, creating a vicious cycle of poverty and illness. Agronursing advocacy must extend beyond individual patient care to support systemic economic protections, agricultural mechanization, and climate-resilient policies that safeguard the financial stability of farming communities. The discipline must collaborate with agricultural economists to quantify the hidden health costs of heat stress and advocate for targeted welfare interventions.

Agronursing practice must evolve to encompass comprehensive, community-based occupational health surveillance and interdisciplinary climate adaptation strategies. The integration of wearable technology and environmental monitoring provides actionable data for identifying critical crop zones and high-risk work shifts, enabling proactive health interventions (Barteit et al., 2025; Parajuli et al., 2026). Community health workers and agronurses are uniquely positioned to deliver culturally competent education on hydration, electrolyte replacement, and recognition of early symptoms of heat-related illness using indigenous knowledge-based approaches (Cemeli et al., 2026; Nyambe et al., 2025). Establishing localized early warning systems and promoting traditional shade structures requires collaborative efforts among healthcare providers, meteorologists, and agricultural leaders to ensure the adoption of wet-bulb globe temperature metrics over simple air temperature readings (Nyambe et al., 2025). The agronursing discipline must champion holistic, worker-centered adaptation policies that safeguard both human health and global food security through evidence-based, multidisciplinary research.

The current body of literature exhibits methodological limitations that necessitate cautious interpretation and guide future agronursing research directions. Many primary studies rely on small convenience samples and cross-sectional designs, limiting statistical power and precluding definitive causal inferences regarding heat exposure and long-term health outcomes (Castellano et al., 2026; Cemeli et al., 2026; Ferro et al., 2025). Self-reported symptom checklists introduce recall bias and may underestimate the true prevalence of severe heat-related illnesses among workers fearing job loss or immigration enforcement (Van Tongeren et al., 2026). Macro-level modeling studies often exclude direct physiological measurements and nighttime urban heat island effects, potentially underestimating the total welfare burden on farming communities (Houessou et al., 2025; Parajuli et al., 2026). Future agronursing research must prioritize longitudinal designs, objective biomarker tracking, and the inclusion of diverse demographic variables to build a robust evidence base for occupational health interventions.

CONCLUSION

This systematic review synthesizes the multifaceted physiological, psychological, and socioeconomic detriments of occupational heat stress among global agricultural populations. Extreme environmental temperatures drive acute renal injuries, severe electrolyte depletions, and profound mental health burdens that disproportionately affect vulnerable outdoor laborers. Agronursing frameworks must urgently integrate continuous physiological monitoring, routine mental health screenings, and gender-responsive occupational policies to protect this high-risk demographic. Translating these empirical findings into actionable public health strategies requires interdisciplinary collaboration to establish localized early-warning systems and enforce stringent thermal-risk regulations. Future investigations must prioritize longitudinal methods and objective biomarker monitoring to elucidate the long-term cascading effects of climate change on farmers' well-being and global food security.

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