



(REVIEW ARTICLE)



Climate resilience and sustainable Anaesthesia practice in African health systems: A systematic review protocol

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Abstract

Objective: To systematically identify, appraise, and synthesize evidence on (i) climate change impacts on anaesthesia services in sub-Saharan Africa, (ii) the environmental footprint of perioperative practice, and (iii) the effectiveness of resilience and sustainability interventions in African health systems.

Methods: This protocol follows PRISMA-P 2015. MEDLINE, Embase, Global Health, and African Index Medicus will be searched from inception to March 2025. Two independent reviewers will screen, extract data, and assess bias using ROBINS-I, RoB 2.0, and AGREE II. Synthesis will follow SWiM, with GRADE certainty assessment.

Anticipated Results: We anticipate identifying a limited but growing body of evidence on climate-anaesthesia interactions in Africa, with substantial heterogeneity precluding meta-analysis. The review will map available evidence, identify adaptation strategies, and highlight critical research gaps.

Conclusion: This systematic review will provide the first comprehensive mapping of Africa-specific evidence on climate change, anaesthesia, and health system resilience, informing locally relevant sustainability guidelines and national adaptation plans.

Keywords: Climate change; Anesthesia; Sub-Saharan Africa; Environmental sustainability; Health system resilience; Perioperative care

1. Introduction

Climate change constitutes one of the most pressing global health threats of the twenty-first century, with disproportionate impacts on low- and middle-income countries in sub-Saharan Africa.¹ The Lancet Countdown reports have documented escalating heat-related mortality, expansion of vector-borne disease transmission, and increasing economic losses attributable to climate change in successive annual assessments from 2022 through 2024.¹⁻³ The African continent, despite contributing the least to global greenhouse gas emissions, bears the greatest burden of climate-related health impacts, a disparity driven by pre-existing health system vulnerabilities, limited adaptive capacity, and socioeconomic constraints.⁴

Within the healthcare sector, anaesthesia and perioperative care represent a significant and growing source of environmental harm. Volatile anaesthetic agents, including desflurane, sevoflurane, and isoflurane, possess global warming potential (GWP) values that exceed carbon dioxide by orders of magnitude when measured over a 100-year horizon.^{5,6} Desflurane, for instance, has a GWP of approximately 2540, making it one of the most potent greenhouse

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gases routinely released in clinical practice.⁶ Nitrous oxide, widely used in obstetric and procedural anaesthesia across Africa, is both a potent greenhouse gas and the dominant ozone-depleting substance currently emitted.⁷ Sherman and colleagues demonstrated through life cycle assessment that desflurane carries approximately fifteen times the greenhouse gas impact of isoflurane and twenty times that of sevoflurane per minimum alveolar concentration hour, while propofol-based total intravenous anaesthesia (TIVA) produces greenhouse gas emissions nearly four orders of magnitude lower than volatile alternatives.⁸

The environmental footprint of perioperative care extends well beyond anaesthetic gas emissions. Operating theatres are among the most energy-intensive spaces in any hospital, requiring stringent environmental controls for temperature, humidity, and air exchange rates that result in substantial energy consumption.⁹ MacNeill and colleagues, in the first carbon footprint study of operating theatres across three health systems, identified anaesthetic gases and energy consumption as the dominant emission sources, with preferential desflurane use driving a ten-fold difference in anaesthetic gas emissions between institutions.⁹ Single-use disposable equipment, pharmaceutical waste, and water consumption further contribute to the environmental burden of surgical care.¹⁰

In sub-Saharan Africa, the intersection of climate change and perioperative care presents uniquely compounded challenges. The region faces a critical shortage of anaesthesia providers, with the World Federation of Societies of Anaesthesiologists (WFSA) Global Anesthesia Workforce Survey documenting physician anaesthetist densities as low as 0.1 per 100,000 population in several countries.¹⁹ Infrastructure limitations, including unreliable electricity supply and intermittent oxygen availability, constrain the adoption of lower-emission alternatives such as TIVA, which depends on continuous power for infusion pumps.²⁰⁻²² The African Surgical Outcomes Study (ASOS) demonstrated perioperative mortality rates approximately twice those observed in high-income settings, underscoring that patient safety considerations must remain paramount even as the profession seeks to reduce its environmental impact.¹⁷ The FEAST trial further illustrated the risks of uncritically extrapolating interventions validated in high-income settings to African contexts, where fluid bolus administration in children with severe infection was associated with increased mortality.¹⁵

Despite these challenges, emerging evidence supports the feasibility and environmental benefit of sustainable anaesthesia practices in diverse settings. The WFSA published a global consensus statement in 2022 establishing seven fundamental principles for environmentally sustainable anaesthesia, developed through a modified Delphi process involving 45 anaesthesia providers from multiple countries.¹⁰ Recent studies have demonstrated that TIVA strategies reduce the carbon footprint of general anaesthesia by up to twenty-fold compared with volatile-based techniques.^{12,13} However, these studies were conducted in well-resourced settings with reliable infrastructure, and their applicability to African practice remains uncertain.

Several national and regional policy frameworks have begun to address the intersection of climate and health in Africa. Joint editorials by African medical journal editors have called for urgent action on climate change at COP27 and subsequent conferences.²³ National surgical, obstetric, and anaesthesia plans (NSOAPs) in Nigeria and other countries have incorporated elements of health system strengthening that could support climate resilience.^{30,31} However, no systematic review has synthesized the evidence on climate-anaesthesia interactions specifically within the African context. This protocol describes a systematic review designed to address this critical evidence gap.

1.1. What is Already Known on This Topic?

- Climate change disrupts healthcare delivery across sub-Saharan Africa through heat-related morbidity, extreme weather events, and infrastructure damage.
- Volatile anaesthetic agents and nitrous oxide are recognized contributors to healthcare greenhouse gas emissions, with desflurane possessing a 100-year global warming potential of approximately 2540.
- Sustainability guidelines developed in high-income countries have not been validated for resource-limited African settings, where infrastructure constraints and workforce shortages alter feasibility.

1.2. What This Study Adds?

- This systematic review will provide a comprehensive, methodologically rigorous mapping of Africa-specific evidence on the intersection of climate change, anaesthesia practice, and health system resilience.
- The review will identify context-appropriate adaptation strategies and highlight critical evidence gaps to guide future research priorities.
- Findings will inform the development of locally relevant sustainability guidelines and support integration of climate resilience into national anaesthesia and surgical care policies.

2. Material and methods

This protocol is reported in accordance with the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P) 2015 guideline.^{32,33} The systematic review will be conducted and reported following the PRISMA 2020 statement.³⁴ The protocol has been developed with reference to the Cochrane Handbook for Systematic Reviews of Interventions, version 6.4.

2.1. Eligibility Criteria

Eligibility will be determined using the PICOS framework (Table 1). Studies will be included if they: (a) focus on health systems or perioperative services in sub-Saharan Africa as defined by the United Nations geographical classification; (b) examine the impact of climate stressors (extreme heat, flooding, drought, storms, sea-level rise) on anaesthesia or surgical service delivery, or evaluate sustainability interventions targeting the environmental footprint of perioperative care; and (c) report on at least one of the following outcomes: service continuity metrics, greenhouse gas emissions or carbon footprint estimates, clinical outcomes related to climate-exposed perioperative care, implementation feasibility, or economic outcomes. Both peer-reviewed and grey literature will be eligible. No restrictions on study design will be imposed; randomized trials, observational studies, qualitative investigations, mixed-methods studies, and clinical guidelines will all be considered. Studies conducted exclusively in high-income countries without African site involvement, editorials without primary data, and conference abstracts without full-text availability will be excluded.

Table 1 PICOS Framework for Eligibility Criteria

Element	Definition
Population	Health systems providing anaesthesia or surgical services in sub-Saharan Africa (UN classification)
Exposure / Intervention	Climate stressors (extreme heat, flooding, drought, storms) or sustainability interventions (low-flow anaesthesia, TIVA, renewable energy, waste reduction, green procurement)
Comparator	Standard perioperative practice; alternative interventions; pre-intervention baseline; or no comparator (descriptive studies)
Outcomes	Service continuity (cancellations, delays); greenhouse gas emissions/carbon footprint; perioperative morbidity/mortality linked to climate exposure; implementation feasibility; economic outcomes
Study designs	Randomised trials, observational studies, qualitative studies, mixed-methods studies, clinical guidelines, and policy analyses

PICOS = Population, Exposure/Intervention, Comparator, Outcomes, Study design; TIVA = total intravenous anaesthesia; UN = United Nations.

2.2. Search Strategy

Table 2 MEDLINE Search Strategy (via PubMed)

Search	Terms
#1	climate change OR global warming OR extreme heat OR heatwave OR flooding OR drought OR cyclone OR environmental sustainability OR greenhouse gas OR carbon footprint
#2	anaesthesia OR anesthesia OR perioperative OR peri-operative OR surgical OR operating theatre OR volatile anaesthetic OR desflurane OR sevoflurane OR isoflurane OR nitrous oxide OR total intravenous anaesthesia OR TIVA
#3	sub-Saharan Africa OR Africa OR Nigeria OR Kenya OR South Africa OR Ghana OR Tanzania OR Ethiopia OR Uganda OR low- and middle-income country OR developing country
#4	#1 AND #2 AND #3

TIVA = total intravenous anaesthesia.

A comprehensive search strategy will be developed in consultation with a health sciences librarian and peer-reviewed using the PRESS (Peer Review of Electronic Search Strategies) 2015 guideline.⁴⁰ The following electronic databases will be searched from inception to March 2025: MEDLINE via PubMed, Embase via Ovid, Global Health via CABI, and African

Index Medicus via the WHO database. Search terms will combine Medical Subject Headings (MeSH) and free-text terms across three conceptual domains: (1) climate change and environmental terms; (2) anaesthesia, perioperative, and surgical care terms; and (3) sub-Saharan Africa geographic terms. The detailed search strategy for MEDLINE is presented in Table 2. Supplementary searches will include citation tracking of included studies, hand-searching of reference lists of relevant systematic reviews, and targeted grey literature searches of WHO AFRO, African Union health policy documents, and national ministry of health publications. No language restrictions will be applied; non-English articles will be translated where feasible.

2.3. Study Selection and Data Extraction

Following deduplication in Covidence (Veritas Health Innovation, Melbourne, Australia), two reviewers will independently screen titles and abstracts against the eligibility criteria. Full texts of potentially relevant records will be retrieved and assessed independently by the same two reviewers. Disagreements at either stage will be resolved through discussion or by a third reviewer. Reasons for full-text exclusion will be recorded and reported in the PRISMA 2020 flow diagram (Fig. 1). Data extraction will be performed independently and in duplicate using a standardized, pilot-tested form (Table 3). Extracted data will include study identifiers, design, setting, population characteristics, exposure or intervention details, comparator, outcomes, key findings, and funding sources. Authors of included studies will be contacted for clarification or additional data where necessary.

Table 3 Data Extraction Framework

Domain	Variables
Study identifiers	Author(s), year, country, journal, DOI, funding source
Design and methods	Study design, sample size, duration, analytical approach
Population and setting	Health facility type, geographic region, urban/rural, patient demographics
Exposure or intervention	Climate stressor type and severity; intervention description, components, and duration
Outcomes	Primary and secondary outcomes, measurement methods, time points, effect estimates
Key findings	Authors' conclusions, stated limitations, reported effect direction and magnitude

DOI = Digital Object Identifier.

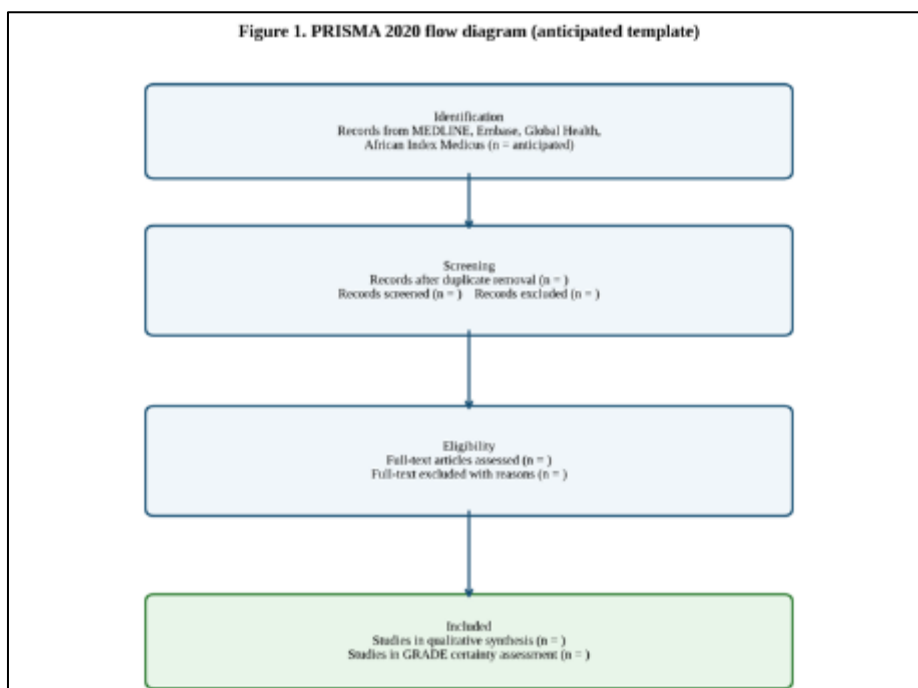


Figure 1 PRISMA 2020 flow diagram

Figure 1 PRISMA 2020 flow diagram showing the anticipated study selection process. AHSR = Archives of Health Science and Research

Fig. 1. PRISMA 2020 flow diagram showing the anticipated study selection process for the systematic review on climate resilience and sustainable anaesthesia practice in African health systems. The diagram follows the recommended PRISMA 2020 template, illustrating the flow from identification through screening, eligibility assessment, to final inclusion. Records will be sourced from MEDLINE, Embase, Global Health, and African Index Medicus, supplemented by grey literature and reference list screening. Two independent reviewers will conduct screening and eligibility assessment, with disagreements resolved by a third reviewer. Reasons for full-text exclusion will be recorded and reported.

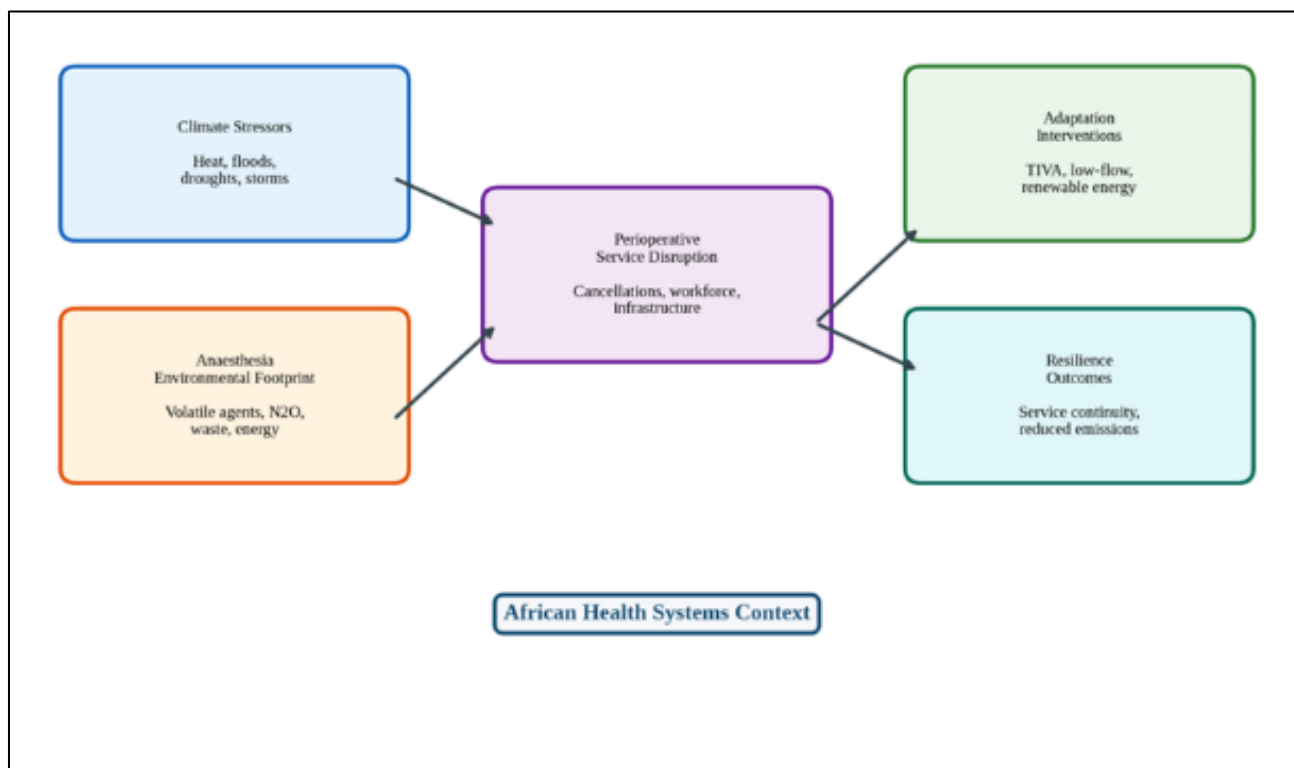


Figure 2 Conceptual Framework : Climate resilience and sustainable anaesthesia in African health system

Fig. 2. Conceptual framework illustrating the pathways linking climate stressors, anaesthesia environmental footprint, perioperative service disruption, adaptation interventions, and resilience outcomes in the context of African health systems. TIVA = total intravenous anaesthesia; N2O = nitrous oxide.

Fig. 2. Conceptual framework illustrating the pathways linking climate stressors (extreme heat, flooding, drought, storms), the anaesthesia environmental footprint (volatile agents, nitrous oxide, waste, energy consumption), and perioperative service disruption (cancellations, workforce challenges, infrastructure damage). Adaptation interventions (total intravenous anaesthesia, low-flow techniques, renewable energy integration) are positioned as modifiable factors that can strengthen resilience outcomes (service continuity, reduced emissions). The framework is situated within the broader African health systems context, recognizing the unique constraints and vulnerabilities of the region. Arrows indicate hypothesized directional relationships between domains.

2.4. Risk of Bias Assessment

Risk of bias will be assessed independently by two reviewers using validated instruments appropriate to each study design (Table 4). Randomized controlled trials will be assessed with the Cochrane Risk of Bias tool (RoB 2.0).³⁶ Non-randomized studies of interventions will be assessed with ROBINS-I (Risk Of Bias In Non-randomized Studies of Interventions).³⁵ Clinical practice guidelines will be appraised using the AGREE II (Appraisal of Guidelines for Research and Evaluation) instrument.³⁷ Disagreements will be resolved by consensus or a third reviewer. Risk of bias assessments will be tabulated and considered in the GRADE certainty-of-evidence evaluation.

Table 4 Risk of Bias Assessment Tools by Study Design

Study Design	Assessment Tool	Key Domains
Randomised controlled trials	RoB 2.0	Randomisation process, deviations from intended interventions, missing outcome data, measurement of outcome, selection of reported result
Non-randomised studies	ROBINS-I	Confounding, selection, classification of interventions, deviations, missing data, measurement, selection of reported result
Clinical guidelines	AGREE II	Scope and purpose, stakeholder involvement, rigour of development, clarity of presentation, applicability, editorial independence

RoB 2.0 = revised Cochrane Risk of Bias tool; ROBINS-I = Risk Of Bias In Non-randomised Studies of Interventions; AGREE II = Appraisal of Guidelines for Research and Evaluation.

2.5. Data Synthesis

Given the anticipated heterogeneity in study designs, populations, interventions, and outcomes, a narrative synthesis following the SWiM (Synthesis Without Meta-analysis) guideline will be conducted.³⁸ Studies will be grouped by thematic domain: (i) climate impacts on perioperative service delivery; (ii) environmental footprint of anaesthesia practice; and (iii) effectiveness and feasibility of sustainability interventions. Within each domain, findings will be synthesized according to the direction and size of effects, consistency across studies, and relevance to the African health systems context. Where studies report quantitative emissions data, these will be tabulated and compared descriptively. Meta-analysis will be considered only if studies are sufficiently homogeneous in design, population, intervention, and outcome measures.

2.6. Certainty of Evidence

The certainty of evidence for each outcome will be assessed using the GRADE (Grading of Recommendations Assessment, Development and Evaluation) approach.³⁹ Evidence from randomized trials will start as high certainty and may be downgraded based on risk of bias, inconsistency, indirectness, imprecision, and publication bias. Evidence from observational studies will start as low certainty and may be upgraded if large effects, dose-response relationships, or plausible confounding effects are present. GRADE certainty assessments will be summarized in a Summary of Findings table.

2.7. Ethics Approval

As this is a systematic review protocol, ethics committee approval is not required. No human or animal subjects are involved. The review will use only publicly available published data.

2.7.1. AI/LLM Usage Statement

The author(s) declared that no AI and/or LLM tool was used in the preparation of this manuscript.

2.7.2. Patient and Public Involvement

No patients or members of the public were directly involved in the development of this protocol. However, the review questions were informed by clinical observations and community health concerns encountered in anaesthesia practice at Lagos State University Teaching Hospital, a tertiary referral center serving a large urban population in Nigeria. The findings of the completed review will be disseminated through open-access publication, conference presentations at African and international anaesthesia meetings, and engagement with national and regional policy stakeholders.

3. Discussion

This protocol describes a systematic review that will address a critical gap at the intersection of climate science, perioperative medicine, and African health systems. The rationale for this review rests on three observations. First, climate change is already disrupting healthcare delivery across sub-Saharan Africa, as documented by successive Lancet Countdown reports and epidemiological studies linking extreme heat and weather events to adverse health outcomes in the region.^{1-3,24,25} Second, anaesthesia and perioperative care contribute meaningfully to healthcare greenhouse gas emissions through volatile anaesthetic agents, nitrous oxide use, and the energy-intensive nature of operating theatre environments.⁵⁻⁹ Third, sustainability guidelines and adaptation strategies developed in high-income countries may not

be directly transferable to African settings, where infrastructure constraints, workforce shortages, and competing health priorities fundamentally alter the feasibility and safety profile of proposed interventions.¹⁹⁻²²

The methodological strengths of this review include a comprehensive, peer-reviewed search strategy spanning four electronic databases and grey literature sources; independent duplicate screening, data extraction, and risk of bias assessment; use of validated assessment tools appropriate to each study design; and a transparent synthesis approach following the SWiM guideline with GRADE certainty assessment.^{38,39} The inclusion of African Index Medicus and regional grey literature is particularly important, as relevant evidence may be published in local journals or institutional repositories not indexed in mainstream databases.

Several limitations are anticipated. The volume and quality of primary evidence addressing climate-anaesthesia interactions in Africa may be limited, reflecting the relative novelty of this research area and the historical under-representation of African health systems in perioperative research. Heterogeneity in study designs, outcomes, and contextual factors is expected, precluding meta-analysis in most instances. Publication bias and selective outcome reporting may further constrain the evidence base, particularly for studies with null or negative findings. The restriction to sub-Saharan Africa, while necessary for contextual relevance, excludes potentially informative evidence from North Africa and other low- and middle-income regions. Despite these limitations, the systematic approach described in this protocol will provide the most comprehensive and methodologically rigorous assessment of the available evidence, identify critical gaps for future research, and generate findings directly applicable to policy and practice in the region.

3.1. Strengths and limitations

Strengths: (1) Comprehensive, PRESS-reviewed search strategy across four databases including African Index Medicus; (2) Independent duplicate screening, extraction, and risk of bias assessment with a third-reviewer resolution mechanism; (3) Use of validated, study-design-specific risk of bias tools (ROBINS-I, RoB 2.0, AGREE II); (4) Transparent synthesis following the SWiM guideline with GRADE certainty-of-evidence assessment; (5) Inclusion of grey literature and no language restrictions to minimize publication and language bias.

Limitations: (1) The evidence base on climate-anaesthesia interactions in Africa may be sparse, potentially limiting the scope of synthesis; (2) Substantial heterogeneity in study designs, outcomes, and contextual factors is anticipated, likely precluding meta-analysis; (3) The geographic restriction to sub-Saharan Africa excludes potentially relevant evidence from North Africa and other low- and middle-income regions; (4) Publication bias may be present, particularly for studies with null or negative findings that may not have been published in indexed journals.

4. Conclusion

This systematic review protocol provides a rigorous, transparent framework for synthesizing evidence on the intersection of climate change, anaesthesia practice, and health system resilience in sub-Saharan Africa. By mapping the available evidence, identifying context-appropriate adaptation strategies, and highlighting critical research gaps, the completed review will inform the development of locally relevant sustainability guidelines for perioperative care. The findings will support national surgical and anaesthesia plans across African countries and provide an evidence base for integrating climate resilience into health policy frameworks. As the healthcare sector increasingly acknowledges its contribution to climate change and its vulnerability to climate impacts, this review will serve as a foundational resource for clinicians, policymakers, and researchers working to ensure that anaesthesia practice in Africa is both environmentally sustainable and resilient to the challenges of a changing climate.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare no conflicts of interest.

Statement of ethical approval

As this is a systematic review protocol, ethical approval was not required. No human or animal subjects were involved. The review will use only publicly available published data.

Statement of informed consent

Informed consent was not required because this study does not involve human participants.

References

- [1] Romanello M, di Napoli C, Green C, et al. The 2023 report of the Lancet Countdown on health and climate change: the imperative for a health-centered response in a world facing irreversible harms. *Lancet*. 2023;402(10419):2346-2394. doi:10.1016/S0140-6736(23)01859-7
- [2] 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. *Lancet*. 2022;400(10363):1619-1654. doi:10.1016/S0140-6736(22)01540-9
- [3] Romanello M, Walawender M, Hsu SC, et al. The 2024 report of the Lancet Countdown on health and climate change: facing record-breaking threats from delayed action. *Lancet*. 2024;404(10465):1847-1896. doi:10.1016/S0140-6736(24)01822-1
- [4] Atwoli L, Erhabor GE, Gbakima AA, et al. COP27 Climate Change Conference: urgent action needed for Africa and the world. *East Mediterr Health J*. 2022;28(11):785-787. doi:10.26719/2022.28.11.785
- [5] McGain F, Muret J, Lawson C, Sherman JD. Environmental sustainability in anaesthesia and critical care. *Br J Anaesth*. 2020;125(5):680-692. doi: 10.1016/j.bja.2020.06.055
- [6] Sulbaek Andersen MP, Sander SP, Nielsen OJ, et al. Inhalation anaesthetics and climate change. *Br J Anaesth*. 2010;105(6):760-766. doi:10.1093/bja/aeq259
- [7] Sulbaek Andersen MP, Nielsen OJ, Sherman JD. Assessing the potential climate impact of anaesthetic gases. *Lancet Planet Health*. 2023;7(7): e622-e629. doi:10.1016/S2542-5196(23)00084-0
- [8] Sherman J, Le C, Lamers V, Eckelman M. Life cycle greenhouse gas emissions of anesthetic drugs. *Anesth Analg*. 2012;114(5):1086-1090. doi:10.1213/ANE.0b013e31824f6940
- [9] MacNeill AJ, Lillywhite R, Brown CJ. The impact of surgery on global climate: a carbon footprinting study of operating theatres in three health systems. *Lancet Planet Health*. 2017;1(9):e381-e388. doi:10.1016/S2542-5196(17)30162-6
- [10] White SM, Shelton CL, Gelb AW, et al. Principles of environmentally-sustainable anaesthesia: a global consensus statement from the World Federation of Societies of Anaesthesiologists. *Anaesthesia*. 2022;77(2):201-212. doi:10.1111/anae.15598
- [11] Seibold EL, Wachtendorf LJ, Needham MJ, et al. Impact of desflurane removal from the operating room on carbon dioxide emissions at a tertiary academic medical center: a retrospective cohort study. *Br J Anaesth*. 2025;135(6):1635-1644. doi: 10.1016/j.bja.2025.05.031
- [12] Narayanan H, Raistrick C, Tom Pierce JM, Shelton C. Carbon footprint of inhalational and total intravenous anaesthesia for paediatric anaesthesia: a modelling study. *Br J Anaesth*. 2022;129(2):231-243. doi: 10.1016/j.bja.2022.04.022
- [13] Bernat M, Boyer A, Roche M, et al. Reducing the carbon footprint of general anaesthesia: a comparison of total intravenous anaesthesia vs. a mixed anaesthetic strategy in 47,157 adult patients. *Anaesthesia*. 2024;79(3):309-317. doi:10.1111/anae.16221
- [14] MacNeill AJ, Rizan C, Sherman JD. Improving sustainability and mitigating the environmental impact of anaesthesia and surgery along the perioperative journey: a narrative review. *Br J Anaesth*. 2024;133(6):1397-1409. doi: 10.1016/j.bja.2024.05.042
- [15] Maitland K, Kiguli S, Opoka RO, et al. Mortality after fluid bolus in African children with severe infection. *N Engl J Med*. 2011;364(26):2483-2495. doi:10.1056/NEJMoa1101549
- [16] Meara JG, Leather AJM, Hagander L, et al. Global Surgery 2030: evidence and solutions for achieving health, welfare, and economic development. *Lancet*. 2015;386(9993):569-624. doi:10.1016/S0140-6736(15)60160-X
- [17] Biccard BM, Madiba TE, Kluyts HL, et al. Perioperative patient outcomes in the African Surgical Outcomes Study: a 7-day prospective observational cohort study. *Lancet*. 2018;391(10130):1589-1598. doi:10.1016/S0140-6736(18)30001-1

- [18] ASOS-2 Investigators. Enhanced postoperative surveillance versus standard of care to reduce mortality among adult surgical patients in Africa (ASOS-2): a cluster-randomized controlled trial. *Lancet Glob Health*. 2021;9(10): e1391-e1401. doi:10.1016/S2214-109X (21)00291-6
- [19] Kempthorne P, Morriss WW, Mellin-Olsen J, Gore-Booth J. The WFSA Global Anesthesia Workforce Survey. *Anesth Analg*. 2017;125(3):981-990. doi:10.1213/ANE.0000000000002258
- [20] Gajewski J, Pittalis C, Lavy C, et al. Anaesthesia capacity of district-level hospitals in Malawi, Tanzania, and Zambia: a mixed-methods study. *Anesth Analg*. 2020;130(4):845-853. doi:10.1213/ANE.0000000000004363
- [21] Hodges SC, Mijumbi C, Okello M, et al. Anaesthesia services in developing countries: defining the problems. *Anaesthesia*. 2007;62(1):4-11. doi:10.1111/j.1365-2044.2006.04907.x
- [22] Apenteng BA, Opoku ST, Ansong D, et al. The effect of power outages on in-facility mortality in healthcare facilities: evidence from Ghana. *Glob Public Health*. 2018;13(5):545-555. doi:10.1080/17441692.2016.1217031
- [23] Atwoli L, Erhabor GE, Gbakima AA, et al. COP27 Climate Change Conference: urgent action needed for Africa and the world. *East Mediterr Health J*. 2022;28(11):785-787. doi:10.26719/2022.28.11.785
- [24] Brimicombe C, Wieser K, Monthaler T, et al. Effects of ambient heat exposure on risk of all-cause mortality in children younger than 5 years in Africa: a pooled time-series analysis. *Lancet Planet Health*. 2024;8(9):e640-e646. doi:10.1016/S2542-5196(24)00160-8
- [25] Arisco NJ, Sewe MO, Barnighausen T, et al. The effect of extreme temperature and precipitation on cause-specific deaths in rural Burkina Faso: a longitudinal study. *Lancet Planet Health*. 2023;7(6): e478-e489. doi:10.1016/S2542-5196(23)00027-X
- [26] Codjoe SNA, Gough KV, Wilby RL, et al. Impact of extreme weather conditions on healthcare provision in urban Ghana. *Soc Sci Med*. 2020; 258:113072. doi: 10.1016/j.socscimed.2020.113072
- [27] Chersich MF, Wright CY. Climate change adaptation in South Africa: a case study on the role of the health sector. *Glob Health*. 2019;15(1):22. doi:10.1186/s12992-019-0466-x
- [28] Schwerdtle PN, Zidouemba DT, Dermbaye AR, et al. Building climate resilience in health systems: a climate vulnerability and capacity assessment in a rural hospital in Chad. *Ann Glob Health*. 2025;91(1):50. doi:10.5334/aogh.4743
- [29] Nilsson M, Sie A, Muindi K, et al. Weather, climate, and climate change research to protect human health in sub-Saharan Africa and South Asia. *Glob Health Action*. 2021;14(sup1):1984014. doi:10.1080/16549716.2021.1984014
- [30] Seyi-Olajide JO, Anderson JE, Williams OM, et al. National surgical, obstetric, anaesthesia and nursing plan, Nigeria. *Bull World Health Organ*. 2021;99(12):883-891. doi:10.2471/BLT.20.280297
- [31] Peters AW, Roa L, Rwamasirabo E, et al. National Surgical, Obstetric, and Anesthesia Plans supporting the vision of universal health coverage. *Glob Health Sci Pract*. 2020;8(1):1-9. doi:10.9745/GHSP-D-19-00314
- [32] Shamseer L, Moher D, Clarke M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. *BMJ*. 2015;349: g7647. doi:10.1136/bmj.g7647
- [33] Moher D, Shamseer L, Clarke M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Syst Rev*. 2015;4(1):1. doi:10.1186/2046-4053-4-1
- [34] Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*. 2021;372: n71. doi:10.1136/bmj.n71
- [35] Sterne JA, Hernan MA, Reeves BC, et al. ROBINS-I: a tool for assessing risk of bias in non-randomized studies of interventions. *BMJ*. 2016;355: i4919. doi:10.1136/bmj.i4919
- [36] Sterne JAC, Savovic J, Page MJ, et al. RoB 2: a revised tool for assessing risk of bias in randomized trials. *BMJ*. 2019;366: l4898. doi:10.1136/bmj.l4898
- [37] Brouwers MC, Kho ME, Browman GP, et al. AGREE II: advancing guideline development, reporting and evaluation in health care. *CMAJ*. 2010;182(18):E839-E842. doi:10.1503/cmaj.090449
- [38] Campbell M, McKenzie JE, Sowden A, et al. Synthesis without meta-analysis (SWiM) in systematic reviews: reporting guideline. *BMJ*. 2020;368: l6890. doi:10.1136/bmj.l6890

- [39] Guyatt GH, Oxman AD, Vist GE, et al. GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. *BMJ*. 2008;336(7650):924-926. doi:10.1136/bmj.39489.470347.AD
- [40] McGowan J, Sampson M, Salzwedel DM, et al. PRESS Peer Review of Electronic Search Strategies: 2015 guideline statement. *J Clin Epidemiol*. 2016; 75:40-46. doi: 10.1016/j.jclinepi.2016.01.021