Key enablers and barriers to climate-smart primary healthcare in South Africa: Insights from climate and health experts

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1. INTRODUCTION AND BACKGROUND

Climate change is one of the most significant global health challenges of the 21st century [1]. It has profound implications for health systems worldwide as rising temperatures, extreme weather events, and shifting disease patterns threaten to exacerbate existing health burdens [1]. This is particularly so in low- and middle-income countries (LMICs) where adaptive capacity is limited [2,3]. Health systems are expected to become climate-smart, i.e. play a pivotal role in mitigating these impacts by strengthening resilience, reducing carbon footprint, and safeguarding population health [4].

Climate-smart PHC integrates climate adaptation, mitigation, and resilience within PHC to maintain essential services, lower health sector emissions, and provide health co-benefits amidst climate change [5]. In LMICs such as South Africa, climate-smart PHC involves strengthening PHC to withstand climate shocks while incorporating low-carbon, resource-efficient practices and community-based adaptation, in accordance with the WHO Operational Framework for climate-resilient and environmentally sustainable health systems [6].

Despite growing recognition of the climate and health relationship, the integration of climate considerations into health policy and practice remains uneven, particularly within PHC, the frontline of service delivery [7]. South Africa is a prime example of this, as while the country has progressive policy frameworks, including the National Climate Change Response Strategy [8] and commitments under the Paris Agreement [9], implementation within the health sector has been slow and fragmented. PHC facilities, which underpin the health system, are especially vulnerable due to resource constraints, infrastructural deficits, and competing priorities such as the dual burden of communicable and non-communicable diseases [10]. Understanding the enablers and barriers to climate-smart PHC is therefore critical to informing policy and practice reforms that align health system strengthening with climate adaptation imperatives [11].

The climate and health relationship is inherently complex and multidimensional, shaped by environmental, social, and political determinants [7]. Globally, climate-sensitive health risks, including heat-related illnesses, vector-borne diseases, and waterborne infections, are increasing in frequency and

44   severity, placing growing pressure on health systems [11,12]. In response, climate-smart health systems

45   advocate integrated approaches that combine adaptation, mitigation, and resilience, with emphasis on

46   governance, infrastructure, financing, workforce capacity, and community engagement [5, 6].

47   In LMICs, these approaches are often weakened by systemic fragility. Limited financial resources,

48   inadequate infrastructure, and workforce shortages constrain the implementation of climate-responsive

49   interventions [13,14]. South Africa faces similar constraints: although national policies acknowledge

50   climate and health linkages, operationalisation at the PHC level remains limited [15]. Many facilities

51   lack the capacity to adopt sustainable technologies or implement effective disaster preparedness

52   measures, while socio-economic inequalities and political inertia further compound vulnerability and

53   undermine resilience [16].

54   Research on how climate change affects health in sub-Saharan Africa is sparse [11], constraining

55   evidence-based decision-making. Without robust local data, there is a risk that adaptation strategies will

56   remain generic and misaligned with contextual realities. Building a strong evidence base through

57   collaborative research and embedding climate considerations into health system planning are essential

58   steps toward resilience, especially in PHC [11].

59   Addressing this deficit demands a holistic, systems-based approach that integrates policy, infrastructure,

60   financing, and community engagement. However, empirical insights into the enablers and barriers of

61   climate-smart PHC in South Africa remain unknown.

62   **2. AIM OF THE STUDY**

63   The study aimed to explore the views of climate and health experts on the enablers and barriers of

64   climate-smart PHC in South Africa.

65   **3. METHODS**

66   **3.1 Study design**

67   An exploratory-descriptive qualitative design was conducted to explore the views of health and climate

68   experts. Data were collected through semi-structured interviews, enabling flexibility to probe emerging

69   issues and capture rich, in-depth insights [17]. Open-ended questions facilitated exploration of diverse

70   perspectives and unexpected themes, contributing to a comprehensive understanding of experts'

71   experiences.

72   **3.2 Study setting**

73   The study was conducted across South African and international contexts to benchmark the current

74   state of practice in South Africa against internationally recognised best practices.

75   **3.3 Participants, sampling and sample size**

76   The participants included experts in health and climate change including nursing educators,

77   policymakers, academics, and managers from both public and private health facilities. Participants were

78   selected based on their background in health and climate change, demonstrated knowledge of the field,

79   and prior involvement in related work, including research, policy development, or publications on

80   health and climate change. A combination of purposive and snowball sampling was used to recruit

81   individuals with expertise in health and climate change. Initial participants were selected based on

82   predefined criteria of a minimum of two years of experience in the health and climate field. Subsequent

83   experts were identified through referrals who recognised them as experts in the field. This approach

84   was appropriate for accessing experts in this still-developing field in South Africa. Sample size was

85   guided by the principle of information power, which prioritises richness and relevance over repetition

86   in qualitative research [18,19]. Thus, 15 in-depth interviews were conducted to enable analytic depth and

87   interpretive richness.

88   **3.4 Data collection**

89   Data collection took place from December 2024 to May 2025. Written consent was sought from all

90   participants before the interviews. A semi-structured interview guide was used to ensure consistency

91   while allowing flexibility for in-depth exploration [17]. Developed through a literature review and co-

92   author consultation, the guide included demographic questions (e.g., position, health and climate change

93   experience) and open-ended questions on contributions to environmental sustainability, public health

94   responses, and health system resilience, with flexibility to capture emerging themes. The guide was

95   piloted with one participant who was not included in the final sample. Feedback led to refinements for

96   clarity and relevance. Additional adjustments were made as new themes emerged during subsequent

97   interviews. The first author conducted the interviews, drawing on her prior knowledge and experience

98   from her master's research, as well as the postgraduate coaching she received through student support

99   services at the university. The researcher conducted all interviews, six in person and the rest online, due

100   to the geographic dispersion of participants. All interviews were in English, as it was the participants'

101   preferred language. With the experts' consent, all interviews were audio-recorded, and their duration

102   ranged from 50 to 90 minutes.

103   **3.5 Data analysis**

104   Interviews were transcribed verbatim within 24 hours and verified by co-authors to ensure data integrity.

105   Reflexive thematic analysis, supported by ATLAS.ti (v25), guided the analytic process [20,21]. Coding

106   was inductive and iterative, with code categories (meaning units) refined as analytic understanding

107   developed. Themes were generated as patterns of shared meaning around central concepts, requiring

108   active interpretive engagement.

109   Analysis followed Braun and Clarke's six phases. Familiarisation involved repeated reading and

110   listening to transcripts. Codes were developed inductively and refined through co-author debriefings.

111   Themes and subthemes were then constructed to capture nuanced patterns and were supported with

112   illustrative data extracts. One co-author independently co-coded four transcripts alongside the lead

113   author; the coding was then compared for consistency before the lead author completed analysis of the

114   remaining transcripts. The final write-up moved beyond description to develop an analytic narrative

115   aligned with the research question.

3.6 Rigour

Trustworthiness was ensured using Lincoln and Guba's (1985) criteria: credibility, transferability, dependability, and confirmability, supported by contemporary guidance [22-24]. Credibility was strengthened through member checking, co-author debriefing, and triangulation across participants and settings. Rich, semi-structured interview data were complemented by the researcher's prior training and engagement with global climate and health networks.

Transferability was supported through detailed contextual descriptions and purposive sampling of diverse climate and health experts. Dependability and confirmability were enhanced through transparent documentation, audit trails, and collaborative coding by the authors. ATLAS.ti facilitated systematic organisation, coding, and visualisation, e.g., Sankey diagrams [25], contributing to analytic coherence. Sufficient data extracts were integrated into the findings to demonstrate the relevance and prevalence of each theme.

3.7 Ethical considerations

Ethics approval was granted by the University of the Western Cape Biomedical Research Ethics Committee (BMREC) (Reference: BM22/10/7). An information sheet was attached to the recruitment email, and consent was obtained after participants reviewed the study details and signed the consent form. Identifying details of experts are deliberately omitted from the results section to ensure anonymity.

4. THEMES IDENTIFIED

4.1 Expert characteristics

The study included 15 experts, with females forming the majority, 11 (73.3%). Academics and researchers dominated the group, accounting for 10 (66.7%) experts, followed by healthcare managers 4 (26.6%), and one policymaker. The experts' years of experience in health and climate ranged from 2

139   to 18 years, averaging 7.4 years. Most experts, 9 (60%) were nurses, four (26.6%) experts were medical

140   doctors, and two (13.3%) experts were public health specialists. (Table 1).

141   Table 1: Expert characteristics

Characteristics	n (%)
Profession	
(i) Nurse	9 (60)
(ii) Medical Doctor	4 (26.6)
(iii) Public health specialist	2 (13.4)
Professional role	
(i) Policy maker	1 (6.7)
(ii) Facility management	4 (26.6)
(iii) University researcher	10 (66.7)
Number of years in the health and climate field	
(i) 2-5years	8 (53.3)
(ii) 6-10years	5 (33.3)
(iii) 11years +	2 (13.3)

142

4.2 Overview of themes identified

144   Two overarching themes were identified: Key enablers of climate change response and barriers to

145   climate resilience that limit the capacity of communities and ecosystems to recover from climate

146   change impacts. Table 2 below illustrates these themes, subthemes and code categories.

Table 2: Overview of themes, subthemes, meaning units and quotes

Themes	Sub-themes	Code categories
1 Enablers of a climate change response	Climate change awareness and dialogue among nurses and other health professionals	Climate change discussions in meetings Raising public awareness of the causes of climate change
	Sustainable infrastructure and resource management	Environmentally friendly travel to reduce carbon emissions in health care Clean energy and increasing energy efficiency within healthcare facilities Climate-resilient infrastructure ensuring that healthcare facilities can withstand extreme weather events
	Education of nurses and other professionals	Pre-service education in nursing on climate change Continuing education on climate change
	Climate resilience initiatives and policies	Actions undertaken by individuals and groups to reduce their environmental footprint Organisational climate resilience practices and policies Governmental-level climate resilience actions and policies.
2 Barriers to climate resilience that hinder the ability of communities and ecosystems to recover	Lack of climate change awareness among nurses and other health professionals	Limited discussions on climate change Nurses' failure to recognise the effects of climate change Challenges to communicating the climate change message

Themes	Sub-themes	Code categories
from climate change impacts	Socio-economic, political, and structural obstacles affecting nurses, other health professionals and the broader healthcare system	Nurses' apathetic attitude towards sustainable activities
		The healthcare system's disease burden influences healthcare prioritisation and resource allocation
		Economic implications of sustainable practices
		Health system's infrastructural challenges
		Human resource constraints in the healthcare system
	Lack of comprehensive strategies to address the complexity of the relationship between climate change and health demands	The impact of climate change depends on contextual factors and the climate resilience of multiple systems, requiring comprehensive strategies
	Limited research and inadequate professional training in addressing the effects of climate change	Lack of research hinders understanding of best practices, impedes the development of innovative solutions
		The nursing curriculum lacks flexibility, hindering its adaptability to incorporate new subjects

4.2.1 Theme 1: Enablers of climate change response

This theme highlighted the climate change awareness and dialogue, and institutional factors that motivate climate change action within the health sector and communities. Participants emphasised that building climate resilience depends on both climate change awareness and dialogue, and structural adaptation within healthcare systems. The theme had four subthemes.

(i)   Climate change awareness and dialogue among nurses and other health professionals

Climate change awareness and dialogue among nurses and other health professionals are crucial for promoting a collective response to environmental challenges. The subtheme spoke of the nurses' understanding and engagement with the effects of changes brought about by the changing climate, which is foundational to implementing effective climate resilience strategies. The subtheme is further broken down into climate change discussions in meetings and awareness of the causes of climate change.

Climate change discussions in meetings bring about awareness of climate change and how to address the effects. One expert indicated how she benefited from an exchange on climate change:

> *They invited people……. They came to talk to us about the initiatives… She was telling us about what they have been doing with climate change in her country and then she also suggested what we could do."* [Nurse educator/Researcher]

PHC facilities could adopt similar initiatives by inviting practitioners who already integrate climate-smart practices into routine care to share practical strategies, making the concept more tangible and actionable.

Awareness of the causes of climate change enhances public understanding and drives collective action. Recognising these causes is essential for adopting effective mitigation strategies and promoting sustainable practices to address the accelerating impacts on our planet.

173   *"I think awareness, the more we are made aware of what's really happening out there, the more*

174   *we as individuals will realise what we need to do now."* [Nurse/Public health services manager]

175   One expert emphasised the environmental impact of excessive paper use, highlighting the lost

176   ecological value of trees.

177   *"Look at all that paper. That paper, it's a lot! It's trees that are supposed to give us oxygen.*

178   *That tree is standing here useless in this office."* [Nurse/ Health facility manager]

179   Another expert raised the environmental concerns associated with healthcare's carbon footprint,

180   particularly focusing on the excessive use of plastics:

181   *"...it's carbon footprint because of the resources used, and I think this is the area where nurses*

182   *are being more responsive from my little experience: the use of plastics, the excessive and the*

183   *unavoidable use of plastics in the healthcare delivery services."* [Nurse educator/Researcher]

184   Social awareness is important as it facilitates the need for one to act to reduce unsustainable practices.

185   **(ii)   Sustainable infrastructure and resource management**

186   Sustainable infrastructure and resource management are vital for creating a climate-smart PHC.

187   Findings show the increasing need for sustainable infrastructure and responsible resource use as

188   foundations for climate-smart PHC. Participants described a spectrum of individual and institutional

189   actions aimed at reducing emissions and promoting sustainability. Building climate-smart infrastructure

190   in health care was also seen as not only involving physical adaptations but also promoting a resilient

191   mindset among healthcare workers.

192   Environmentally friendly travel is one way that was identified as a means to reduce carbon emissions

193   in health care. Many professionals are adopting alternative transportation methods to lower their carbon

194   footprint.

195   *"I changed job and I decided to go to this new job where l can travel by train instead… So I'm*

196   *cutting down my emissions by going by train and nothing else at the moment".* [Nurse

197   educator/Researcher]

198 Adopting clean energy and improving energy efficiency in healthcare facilities are key to cutting down

199 carbon emissions and costs. Experts stressed their commitment to renewable energy, with one

200 highlighting proactive effort in their educational workplace to reduce fossil fuel reliance and combat

201 climate change through renewable sources.

202   *"So in the energy space, what we're committed to here is to also be carbon neutral by 2030...*

203   *our plan is that a third of our energy will come from solar. We're already installing solar on*

204   *the roofs. And that another proportion will come from further changes to the efficiency of*

205   *infrastructure."* [Specialist family physician/Academic/Researcher]

206 PHC facilities can also adopt clean energy solutions to reduce their carbon footprint and become

207 climate-smart.

208 Building climate-resilient infrastructure involves using sustainable materials and designs to withstand

209 climate impacts. One expert noted the increasing trend in healthcare infrastructure toward integrating

210 eco-friendly elements to boost energy efficiency and resilience.

211   *"But if you do look at the newer hospitals that are being built these days, there are some of the*

212   *private hospitals that have incorporated the green aspects, and you can see the natural*

213   *lighting."* [Nurse educator/Researcher]

214 Another expert called for a critical evaluation of building materials in the context of climate-resilient

215 infrastructure:

216   *"I think we need to look at the type of materials that we are using. How long do they last? Are*

217   *they environmentally friendly? Maybe it's having to look at those types of things instead of*

218   *using plastic for this, can we have something different that's more environmentally friendly?"*

219   [Nurse/District health facilities manager]

220   Building climate-resilient infrastructure in healthcare involves not only physical adaptations but also

221   promoting a resilient mindset among healthcare workers:

222   *"We need a resilient climate mindset in a nurse that can protect the hospital from future*

223   *flooding, reduce carbon dioxide emissions through responsible procurement… minimise the*

224   *hospital's energy and environmental footprint. By understanding the importance of green*

225   *energy, a nurse empowers herself and her colleagues through knowledge, education, and*

226   *awareness of climate change's impact on health and healthcare."* [Public health

227   specialist/Academic/Researcher]

228   **(iii)   Education of nurses and other health professionals**

229   Acquiring knowledge of climate change is crucial for effective adaptation and mitigation strategies that

230   are pivotal in climate-smart PHC. The subtheme elicited pre-service education in nursing on climate

231   change as a way to equip future nurses with essential knowledge and skills to address environmental

232   impacts on health. One expert accentuated the importance of nursing education in comprehending and

233   tackling the impacts of climate change. They emphasised the necessity for nurses to understand

234   adaptation and mitigation concepts:

235   *"I think that the nurses' education at this point is key to be able to educate the population, the*

236   *nurses need to be educated about what it means, adaptation and what it means, mitigation, and*

237   *why these two are different."* [Medical doctor/Researcher]

238   As climate change increasingly affects health, ongoing education for healthcare professionals is

239   essential.

240 *"So firstly they have to have the knowledge and the understanding. I didn't have this before*

241 *even though I've been in this for very long. And so if you don't have the knowledge then you*

242 *can't preach what you want to."* [Nurse educator/Researcher]

243 Another expert added:

244 *"So providing just the basic kind of information for nurses so that they understand what's*

245 *climate change, where's the evidence? Why should we be worried about it as nurses? How is it*

246 *impacting our communities?"* [Nurse educator/Researcher]

247 The experts echoed the need to continuously engage the nurses with the current disease trends to be

248 able to cope with changing healthcare needs.

249 **(iv) Climate-resilience initiatives and policies**

250 Effective climate-resilience initiatives and policies are necessary to ensure climate-smart PHC that will

251 safeguard health and well-being. The sub-theme identified the initiatives and policies that are in use.

252 To adapt and mitigate the effects of climate change, organisational climate resilience practices and

253 policies constitute the formal and informal rules that guide behaviour and decision-making within an

254 organisation. These frameworks influence operational efficiency, employee behaviour, and

255 organisational culture, and ensure alignment with reducing the carbon footprint of the organisation. One

256 expert expressed:

257 *"We use the hybrid system of working. So we don't need to use our vehicles every day because*

258 *we work from home and we work from the office."* [Nurse/Public health facilities manager]

259 Governmental-level climate-resilience policies encompass the strategic measures and regulatory

260 frameworks through which national and sub-national authorities strengthen the health sector's capacity

261 to anticipate, withstand, and respond to climate risks, in line with WHO guidance urging integration of

262 climate risk across health-system functions, alignment of mitigation and adaptation, and development

263 of a climate-smart health workforce.

264 One expert indicated:

265 *"Now there's the climate change bill and the climate adaptation response strategy from South*

266 *Africa, so those are the policies that are at the national level that are dealing with climate*

267 *change."* [Nurse/Policymaker]

268 Also, there is movement towards making carbon-neutral measures compulsory, as identified by one of

269 the experts:

270 *"The City of Cape Town is one of the C40 cities, and so there's a commitment to being carbon*

271 *neutral by 2050... So now, the departments of the province have received a directive to declare*

272 *how they are going to contribute to going carbon neutral. So the Department of Health has set*

273 *up a climate change forum, who seem to be preoccupied with mitigation to contribute to that*

274 *goal… they also joined the Global Green and Healthy Hospital Network."* [Nurse/ Policy

275 maker]

276 Building climate-smart PHC and communities involves enhancing climate change awareness of nurses

277 and other health professionals, developing sustainable infrastructure, acquiring climate knowledge, and

278 implementing climate-resilient initiatives and policies. These elements collectively empower

279 communities and healthcare systems to effectively respond to climate challenges and ensure

280 sustainability.

4.2.2 Theme 2: Barriers to climate resilience that limit the capacity of communities and ecosystems to recover from climate change impacts

283 This theme highlighted systemic and contextual barriers that hinder communities and ecosystems from

284 preventing and recovering from the effects of climate change. Expert participants identified four core

285 barriers: lack of climate change awareness among nurses and other health professional, socio-economic,

286 political, and structural challenges, the complexity of the climate and health relationship, and limited

287 research and inadequate professional training of nurses. Each barrier constrains a climate-smart PHC

288 system in South Africa.

289 **(i)** **Lack of climate change awareness among nurses and other health**

290 **professionals**

291 Lack of climate change awareness among nurses and other health professionals is the insufficient

292 understanding of climate change's causes, impacts, and urgency, leading to inadequate responses and

293 inaction. It is discussed as limited discussions on climate change, failure to recognise the effects of

294 climate change, and challenges to communicating the climate change message.

295 Limited discussions on climate change involve insufficient engagement across professional education,

296 media, policy, and public discourse, hindering awareness and action. One expert noted the absence of

297 climate change training in current in-service education for nurses.

298 *"No, there isn't any specific education on climate change."* [Nurse/District facilities manager]

299 Another expert noted that they do not currently include information on climate change in their health

300 education sessions:

301 *"But we definitely don't have it in the hospital. We're definitely not giving this kind of*

302 *information to patients in the emergency department or wherever as health education*

303 *information."* [Nurse educator/Researcher]

304 The provincial policymaker highlighted that frontline nurses may lack formal awareness of climate

305 change, as they have not received comprehensive education on the subject:

306 *"For me, I only know it's my job, but ordinarily, nobody would know what we're talking about.*

307 *So you cannot be able to say, therefore, I found that nurses are not ready for climate change,*

308 *because they don't know what we're talking about."* [Nurse/Provincial policy maker]

309   Limited awareness of climate change impacts leads to a failure to recognise its effects on ecosystems,

310   societies, and economies. This lack of recognition delays mitigation and adaptation efforts, hindering

311   resilience and sustainability. One expert linked this to a lack of urgency in addressing climate issues.

312   *"So, I think that there is an analogy there between the COVID-19 experience and climate*

313   *change, but people don't recognise climate change, or they don't see it as immediate."* [Medical

314   doctor/Researcher]

315   Another expert concurred, saying:

316   *"… but I think we don't know what is already at the front door… and it might… be a little bit*

317   *too late. I think we should have done it a long time ago already. Start focusing on our impact*

318   *on climate change. I do believe that there's not enough done."* [Nurse/Private health services

319   manager]

320   A public health specialist added that nurses are often unaware of the climate change effects they

321   encounter in their daily work:

322   *"That's quite important for the nurse because, as clinicians, they often don't see the link*

323   *between climate change's impact on health and their work, and it appears to be contradictory*

324   *because these are the effects they are dealing with… the effect of climate change every day."*

325   [Public health specialist/Academic/Researcher]

326   Challenges in communicating climate change hinder awareness among nurses by creating barriers to

327   conveying its urgency and relevance. One expert noted that the intimidating nature of climate change

328   can discourage discussions.

329   *"... people don't want to talk about climate change because it scares them, having to be told*

330   *that the environment can no longer sustain life. I feel the pioneers on the education of climate*

331   *change need to try and demystify it and put it in a way that gives hope to people that it is*

332   *something that we can deal with."* [Medical doctor/Researcher]

333   There is also a need to simplify the knowledge of climate change for nurses by breaking it down into

334   easily understandable segments:

335   *"What is it that they're saying we should be saying to people and how should we be conveying*

336   *this message? I think it's something that needs to be coming from the start of your nursing*

337   *career… It's not just about nurses… it's all healthcare professionals and what is the message*

338   *that we want to say? Are we going to go and tell everybody, don't fly and don't make open fires*

339   *and don't... I don't know what we are going to tell them. I think that's the problem because*

340   *climate change is so huge."* [Nurse educator/Researcher]

341   The same expert reiterated:

342   *"We also have to think about how we package the message and what it is we want to say. And*

343   *I think that's not clear. We haven't spent enough time thinking about what that needs to be, so*

344   *it's not just the problem for the Primary Health Care nurse. It goes back and it's actually from*

345   *the Department of Health and everything."* [Nurse educator/Researcher]

346   Enhancing climate change awareness among nurses is essential for promoting informed decision-

347   making, promoting sustainable behaviours, and mobilising collective action to address environmental

348   threats effectively.

349   **(ii)   Socio-economic, political, and structural obstacles affecting nurses, other health**

350   **professionals and the broader healthcare system**

351   Socio-economic, political, and structural constraints remain central obstacles to achieving climate-smart

352   PHC. Deep-rooted inequities in wealth, governance capacity, and service delivery infrastructure reduce

353   the ability of facilities and communities to anticipate and adapt to climate impacts. These systemic

354   disparities create uneven vulnerability profiles, impede equitable resource allocation, and undermine

355   the implementation of climate-related policies, ultimately weakening adaptive capacity across the health

356   system. Beyond structural barriers, behavioural and perceptual factors also shape the uptake of climate-

357 smart practices. Nurses' attitudes toward climate change influence how information is interpreted and

358 acted upon; limited awareness, scepticism, and perceived inconvenience can create apathy, slowing

359 mitigation and adaptation efforts. As one expert observed, even nurses, who are often regarded as

360 trusted public role models, do not consistently demonstrate environmental stewardship, highlighting a

361 critical gap between professional influence and climate-responsible behaviour.

362   *"But the problem is that it's like trying to teach a diabetic not to eat sugar when you, as a nurse*

363   *or a diabetic you're being bad yourself… that's a problem. I can't be telling everybody all these*

364   *things they must be doing to prevent climate change when I'm sitting at home with my air*

365   *conditioner on and I'm thinking how I'm going to be flying down to Joburg, doing all the things*

366   *that are adding to it too."* [Nurse educator/Researcher]

367 The issue of apathy, as coming from a lack of interest and being preoccupied with other work

368 commitments, was also identified as a barrier:

369   *"I have been motivating people in our department to get involved. I just find that people are so*

370   *very involved with what they are doing and just managing to go through the teaching and*

371   *learning program that it is a challenge to get them to just listen to what you say and get*

372   *involved."* [Nurse educator/Researcher]

373 Apathy can hinder behaviour change, as nurses may resist adopting sustainable practices due to comfort

374 with current habits, scepticism, cultural norms, or perceived inconvenience. Disease burden,

375 representing the impact of health conditions on a population, can also impede climate resilience by

376 affecting healthcare priorities and resource allocation.

377 One expert noted that the healthcare system's focus on curative services makes it difficult to prioritise

378 preventive and environmental health measures.

379   *"We want to prevent and promote health instead of having to deal with curative…, but we are*

380   *currently so overwhelmed by the curative clients that we've got to see it is a big challenge to*

381   *the system. How does the system breathe when we think it's a day-to-day thing, the number of*

382   *clients, and there isn't even room to say, we now need to stop and look at what we are doing*

383   *and how we can implement change? And if there is a need for change, what change do we*

384   *need?"* [Nurse/District facilities manager]

385 Relatedly, the substantial disease burden in the region is a major concern:

386   *"We are sitting with a true dilemma within the African context. And if you put on top of that all*

387   *the other problems that we're sitting with in Africa, such as the HIV burden, malnutrition, so*

388   *all these other public health concerns and socio-economic and political concerns all*

389   *compound. So whatever problems already exist within our context, climate change intensifies*

390   *it exponentially."* [Medical doctor/Researcher]

391 The economic consequences to the healthcare system and the country of sustainable activities include

392 costs, benefits, and broader financial impacts. While such activities aim to reduce waste and resource

393 use, their implementation can involve substantial financial investment. One expert brought up the

394 financial challenges of making the switch to clean energy, highlighting the importance of striking a

395 balance between environmental aims and economic stability of the country. Economic challenges

396 prevent the country from adopting sustainable practices:

397   *"By following the news, I found out about Eskom* (South Africa's state-owned electricity utility)

398   *and the money involved. They don't want to give us the money because we are not able to get*

399   *rid of that coal and diesel."* [Nurse/Facility manager]

400 Another expert added:

401   *"South Africa also has an economy that is very dependent on coal for electricity production...*

402   *so if we get other ways of generating electricity, it takes a lot of business ... and food out of*

403   *people's mouths. And that's also an incentive for people not to go that fast with initiatives to*

404   *deal with the matter."* [Nurse educator/Researcher]

405   The healthcare system infrastructural challenges impede climate resilience by limiting the development

406   and efficiency of systems and services in an eco-friendly manner. Overcoming these barriers is crucial

407   for sustainable development and adapting to environmental changes. One expert mentioned difficulties

408   in transitioning to virtual meetings or structural challenges within hospitals:

409   *"In a lot of places in Africa, the internet is very intermittent, so you can't say to people let's not*

410   *travel. We'll do things this way because chances are it's not going to work out very well…"*

411   [Nurse educator/Researcher]

412   Another expert added:

413   *"But our hospitals are old, they don't have proper air conditioning, they don't have windows*

414   *that open, so sometimes people then make use of air conditioning. Air conditioning makes the*

415   *situation worse. They don't have natural lighting, so you have to use a lot of electricity to burn*

416   *lights and air conditioners. Lots of these hospitals are in the city and their grounds are not*

417   *able to be used. If you look at where the big tertiary hospitals are, it's in the middle of where*

418   *people live. So, it's large, it's old-fashioned. It's just not organised for a green situation."*

419   [Nurse educator/Researcher]

420   Furthermore, road infrastructural challenges hinder clean modes of travel:

421   *"If the responsible stakeholders can make our roads a little bit more user-friendly, especially*

422   *your other modes of transport like a bicycle, I would cycle to work instead of using my vehicle.*

423   *Our rail system is in a mess at the moment. If we can get that up to speed, more people can use*

424   *rail. ...and if My City bus* (City of Cape Town bus system) *can roll out to more areas within*

425   *the city."* [Nurse/Public health services manager]

426   Inadequate governance structures and conflicting policy priorities can also lead to fragmented and

427   ineffective responses, as identified by one expert:

428   *"We've got all the policies, but there are gaps as far as implementation plans are concerned.*

429   *... for example, heat action plans are concrete, but there is confusion around ownership to lead*

430   *these action plans and the capacity to be able to implement these plans is also lacking."*

431   [Medical doctor/Researcher]

432 Experts also identified human resource constraints in the healthcare system as a significant obstacle.

433 One expert spoke of a shortage of nurses at the facility level:

434   *"I'm not just thinking in terms of what's currently happening. ... with all the budget cuts that*

435   *have been done and having to shift what we are doing with our staffing and when l think of how*

436   *that's impacting us at this moment... I don't think I can still include another staff member for*

437   *this, I can't. I'm already struggling with the little that I've got."* [Nurse/District facilities

438   manager]

439 Another expert mentioned the overarching issue of human resource shortages:

440   *"But I think we also simply don't have enough nurses. So one would have to look also at*

441   *environmental health practitioners and auxiliary nurses. And in terms of mental health, one*

442   *would have to look at lay counsellors and that kind of thing. We simply just don't have, in South*

443   *Africa or Sub-Saharan Africa, sufficient human resources in health."* [Medical

444   doctor/Researcher]

445   **(iii)   Lack of comprehensive strategies to address the complexity of the**

446   **relationship between climate change and health demands**

447 The relationship between climate change and health is complex, involving complex interactions

448 between environmental changes and human well-being. This intricate linkage demands comprehensive

449 strategies to mitigate adverse health outcomes and enhance adaptive capacity. The sub-theme has the

450 meaning unit: the impact of climate change depends on contextual factors and the climate resilience of

451 multiple systems, requiring comprehensive strategies. This was illustrated by several experts in various

452 ways; for instance, one expert indicated:

453 *"And I think the problems that climate change causes can also be due to other things. So it's*

454 *hard to tease out exactly what's the problem from climate change and or whether this is being*

455 *caused by something else, because I think they're all factors that come together to create this*

456 *particular problem."* [Nurse educator/Researcher]

457 Another expert described climate resilience as depending on the strength and resilience of the country's

458 infrastructure:

459 *"But I mean the other piece of that is the ability of those proximate causes to impact health and*

460 *the social effects depend on a whole lot of other modifiers. The strength and resilience of the*

461 *health system, the strength and sort of preparedness of the governance structures in the country,*

462 *the wealth of the country, whether you're low-income, high-income, sometimes even sort of the*

463 *beliefs and the culture, all these things can affect the sort of resilience of the society or the*

464 *community. So in some places, the same proximal cause will be devastating, in another place*

465 *it will be sort of mildly irritating."* [Specialist family physician/Academic/Researcher]

466 **(iv) Limited research and inadequate professional training in addressing the**

467 **effects of climate change**

468 Limited research and inadequate professional training hinder the effective response to climate change's

469 impacts on health and ecosystems. The capacity of professionals to design and carry out evidence-based

470 climate solutions is compromised by gaps in knowledge and competency brought about by a dearth of

471 focused research and educational initiatives. This shortcoming stifles creative thinking, inhibits

472 sustainability advancement, and limits sound decision-making for environmental resilience and

473 sustainable development. One expert observed:

474   *"So, there's not much research. You are the first one in my nursing career of 45 years who*

475   *asked me about going green* (this is what sustainability activities are also called by some)*. So,*

476   *there are not many studies about going green."* [Nurse/Health facility manager]

477   Another expert described it as a lack of focus on a particular aspect:

478   *"So we've done a scoping review… on primary health care and climate change in Africa. What*

479   *that review tells us is that there's not a lot of actual hard evidence or research... there are a lot*

480   *of anecdotes and expectations and descriptions and sort of opinions …"* [Specialist family

481   physician/Academic/Researcher]

482   Experts identified an inflexible nursing curriculum as a key barrier to climate resilience, as it limits the

483   integration of emerging priorities such as sustainability and climate change. This makes it harder for

484   nurses to adjust to new problems in healthcare. One expert made the following observation:

485   *"I think nurses are much more into their regulations than other disciplines and l don't know*

486   *how easy that will be if it's not somehow stated in the Nursing Council curriculum. It seems like*

487   *they will have to have that support from that level up going down. Other professions are not so*

488   *rigid in regulatory approach."* [Specialist family physician/Academic/Researcher]

489   A curriculum gap in climate change content was highlighted by a Nurse educator:

490   *"And but no, so there isn't. It's probably just a few of us who talk about it every now and again,*

491   *but formally not much. I might just bring it up, in terms of emergency care in opportunities*

492   *where I get to speak, but that's just it, it's not formally in the curriculum, no."* [Nurse

493   educator/Researcher]

494   Lack of sustainability topics was also noted to be absent in other curricula as one expert stated:

495   *"Not yet, but I can't speak on behalf of the entire institution, but I'm only speaking on behalf*

496   *of the department that I'm working in. So as far as I know, I am not aware of any curriculum*

497   *that is included for students that speaks to climate change."* [Medical doctor/Researcher]

498 Building resilience requires an understanding of the health effects and ecosystem implications of

499 climate change. Strong legislation, sustainable practices, societal consciousness, and behavioural

500 adjustments are all necessary for effective climate action. However, efforts to adapt and mitigate the

501 effects are hampered by apathy, disease loads, economic costs, infrastructure problems and human

502 resources shortages.

503

5. DISCUSSION

5.1 Discussion of key findings

506 The emergence of climate-smart PHC requires climate change awareness and dialogue among nurses,

507 sustainable infrastructure, education of nurses and other health professionals, and the presence of

508 climate-resilience initiatives and supportive policies. In addition, barriers such as nurses' limited

509 awareness, socioeconomic, political, and structural obstacles across nurses and the healthcare system,

510 the complex relationship between climate change and health, and gaps in research and professional

511 training should be identified and addressed. These findings are described under four key themes (1)

512 Climate change awareness and dialogue among nurses; (2) Socio-economic, structural, and political

513 constraints across nurses and the healthcare system; (3) Complexity of climate and health relationships

514 and systems approach; and (4) Research, education, and professional capacity-building. These

515 categories provide an integrated lens through which to understand the opportunities and challenges

516 influencing climate-smart PHC implementation, particularly in LMIC contexts.

517

5.2.1 Climate change awareness and dialogue among nurses

519 Limited climate change awareness, dialogue and a weak professional discourse on climate change

520 emerged as foundational barriers to advancing climate-smart PHC. Experts noted that climate change

521 remains peripheral within routine healthcare discussions, with few structured platforms that enable

522 practitioners and policymakers to engage meaningfully on climate and health risks. This reflects broader

523   patterns across many LMICs, where environmental health concerns often compete with immediate

524   clinical demands and chronic resource shortages, limiting sustained attention to climate-related threats

525   [7]. In the South African PHC context, this low level of awareness further undermines nurses' ability

526   to recognise and manage climate-sensitive conditions, such as vector-borne, respiratory, and water-

527   related diseases [11]. This constrains early detection, prevention, and adaptive responses. Insufficient

528   awareness among health workers constrains adaptation capacity and limits advocacy for climate and

529   health policies [14,16]. Some health and climate experts expressed ambivalence, citing personal

530   inconsistencies in sustainable behaviour. These findings echoed those of a study on eco-anxiety and

531   environmental education that found low self-efficacy as a barrier to climate action [28].

532   In the context of limited awareness, experts emphasised that participatory engagement and sustained

533   dialogue are critical enablers of climate-smart PHC, particularly in LMICs where collective action often

534   compensates for systemic constraints. Open discussions on climate and health linkages within

535   healthcare teams and communities were seen as essential for creating shared responsibility and

536   strengthening moral commitment to climate-responsive care. These views echo global literature that

537   emphasises health professionals' ethical obligation to advocate for climate action and educate the public

538   [26]. This is reinforced by the International Council of Nurses' revised definition of nursing, which now

539   includes promoting sustainable environments [27]. Strengthening communication strategies across

540   professional networks, community outreach structures, and continuing education platforms may

541   therefore help translate awareness into coordinated action within PHC. International studies similarly

542   report that insufficient awareness among health workers limits adaptation capacity and undermines

543   advocacy for climate-health policies [14,16]. Some experts also expressed ambivalence due to personal

544   inconsistencies in sustainable behaviour, reflecting broader LMIC findings on low self-efficacy and

545   eco-anxiety as barriers to climate action [28].

546   **5.2.2 Socio-economic, structural, and political constraints across nurses and**

547   **the healthcare system**

Socio-economic disparities, infrastructural limitations, and governance challenges in the healthcare system are critical barriers to advancing climate-smart PHC in LMICs. The dual burden of communicable and non-communicable diseases, coupled with constrained budgets and workforce shortages, often relegates environmental priorities to the margins. Similar patterns are documented globally, where economic fragility reduces adaptive capacity [16,29]. Across LMICs, overstretched PHC facilities struggle to implement low-carbon technologies or climate-resilient infrastructure despite policy commitments, reflecting what international literature terms the "resilience deficit" [14,30].

Addressing these systemic constraints requires targeted investment in infrastructure, governance, and workforce development, aligned with national health and climate frameworks. Many LMICs have adopted climate adaptation strategies and universal health coverage reforms, which emphasise integrated planning, institutional capacity, and resource allocation to build climate-smart health systems [30,31]. These frameworks substantiate the need to channel investment into service platforms, governance capabilities, and workforce pipelines in ways that cohere with health system strengthening and national climate response architecture.

This multidimensional understanding echoes findings that climate and health vulnerabilities arise from overlapping determinants of environmental degradation, inequality, and governance capacity [29]. For LMICs, these observations reinforce the need for holistic, systems-based planning that integrates social protection, environmental health, and public health surveillance within PHC [31]. Sustainable infrastructure and resource management are indispensable for climate-smart PHC. Adoption of clean-energy solutions, eco-efficient building designs, and green procurement practices offers a pragmatic entry point. Evidence shows that climate-smart PHC facilities incorporating solar power, natural ventilation, and sustainable materials can improve operational efficiency and environmental stewardship [32].

5.2.3 Complexity of climate and health relationships and systems approach

Experts stressed that being climate-smart cannot be confined to the health sector alone; it relies on adaptive capacities across ecosystems, food systems, housing, and water infrastructure, and aligns with

574 the PHC approach. This systems-based perspective reflects the planetary health framework, which calls

575 for synergistic action across human and ecological domains [33,34]. However, in LMICs, coordination

576 between the health, environment, and municipal sectors remains fragmented, often resulting in reactive

577 rather than preventive interventions. Strengthening intersectoral governance, particularly at the PHC

578 level, could enhance coherence between environmental and health planning.

579

580 ## 5.2.4 Research, education, and professional capacity-building

581 A persistent gap in climate and health research, together with inadequate professional training,

582 continues to limit the capacity of health systems to respond to emerging climate-related challenges. The

583 scarcity of empirical evidence hampers understanding of local vulnerabilities and the development of

584 effective adaptation models, echoing trends reported across sub-Saharan Africa [11]. Experts

585 emphasised the need for collaborative, practice-oriented research to generate contextually relevant

586 interventions, noting that without such evidence, both innovation and policy development remain

587 constrained [11].

588 Education and capacity-building were viewed as equally critical. Experts pointed to the rigidity of

589 nursing curricula, which limits the integration of climate change, sustainability, and planetary health

590 content, an issue reflected in global calls for curriculum reform to better prepare practitioners for

591 emerging planetary health challenges [14,35]. Embedding these concepts in both pre-service and in-

592 service training would position nurses, the largest segment of the health workforce, to lead adaptation,

593 mitigation, and resilience efforts within PHC settings. International best practice further emphasises the

594 value of linking environmental stewardship with professional ethics and public health outcomes [30].

595 ## 6. STRENGTHS AND LIMITATIONS OF THE STUDY

596 The study included a diverse range of participants, from nurses to medical doctors and public health

597 specialists, capturing a broad spectrum of perspectives. However, recruitment relied on online

598 identification of individuals working in health and climate change and on snowball sampling, which may

599 have excluded those outside these networks. The sample was also predominantly female and largely drawn

600 from academic settings.

7. IMPLICATIONS

From the study, it can be deduced that strengthening climate-smart PHC in LMICs requires embedding climate-risk assessment, operational preparedness, and low-carbon technologies into routine PHC practice. In nurse education, it entails integrating climate and health competencies into pre-service and in-service training to build a workforce capable of climate-responsive care. In the policy sphere, there is a need to align PHC governance, financing, and infrastructure investment with national climate and health frameworks to ensure coherent implementation and sustainability.

8. CONCLUSION

Climate-smart PHC is not a discrete technical intervention but a multidimensional systems transformation requiring coordinated action across sectors. Insights from climate and health experts in this study accentuate that strengthening climate-smart PHC in LMICs depends on recognising the interlinked social, professional, structural, and policy conditions that shape effective climate responses. Addressing barriers, ranging from limited climate awareness and communication gaps among nurses to entrenched structural and resource constraints, must occur alongside investments in professional education, sustainable infrastructure, and policy coherence. Although nurses are pivotal frontline actors in climate adaptation and mitigation, especially in PHC, their potential remains underutilised. Embedding climate literacy and sustainability principles into health policy, facility management, and nursing education can catalyse a shift toward resilient, low-carbon PHC systems capable of safeguarding population health in an increasingly unstable climate.

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9.1 Competing interests

Nil

9.2 Authors contributions

All authors conceptualised the study. TS collected and analysed the data, drafted the article and edited it. JC supervised the study, validated data and wrote, reviewed and edited the article. TC supervised the study, validated and analysed data and wrote, reviewed, and edited the article.

9.3 Funding information

9.4 Data availability

Not applicable

9.5 Disclaimer

The views and opinions expressed in this article are those of the authors and are the product of professional research. It does not necessarily reflect the official policy or position of the affiliated institution, or that of the publisher. The authors are responsible for this article's results, findings and content.

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