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► **To cite this version:**

Monika dos Santos, David Howard, Pieter Kruger, Arnaud Banos, Saul Kornik. Climate Change and Healthcare Sustainability in the Agincourt Sub-District, Kruger to Canyons Biosphere Region, South Africa. *Sustainability*, 2019, 11 (2), pp.496. 10.3390/su11020496 . hal-01993273

HAL Id: hal-01993273

<https://hal.science/hal-01993273v1>

Submitted on 4 Sep 2023

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Article

Climate Change and Healthcare Sustainability in the Agincourt Sub-District, Kruger to Canyons Biosphere Region, South Africa

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Received: 13 November 2018; Accepted: 14 January 2019; Published: 18 January 2019



Abstract: As low-income communities are most vulnerable to climate-associated health concerns, access to healthcare will increase in importance as a key priority in South Africa. This study explores healthcare sustainability in the Agincourt sub-district, Kruger to Canyons Biosphere Region in Mpumalanga, South Africa. A rapid assessment and response methodology (RAR) was implemented, which includes the examination of previous studies conducted in the sub-district, the mapping of healthcare facilities in the area, and the implementation of a facility infrastructure and workforce capacity investigation by means of key informant (KI) interviews at eight healthcare facilities. Findings indicate that the greatest need across the facilities relate to access to medical doctors and pharmacists. None of the facilities factored climate associations with health into their clinical care strategies. The necessity to train healthcare facility staff on aspects related to climate change, health, and sustainability is highlighted. Environmental health practitioners should also be incorporated in grassroots community climate adaptation strategies. Outcomes further indicate the need for the advancement of integrated healthcare and climate adaptation strategies that focus on strengthening healthcare systems, which may include novel technological approaches such as telemedicine. Policy makers need to be proactive and pre-emptive in finding and improving processes and models to render healthcare services prepared for climate change.

Keywords: climate change; healthcare; sustainability; healthcare system strengthening; low-income communities; Agincourt; South Africa

1. Introduction

Climate change impacts human wellbeing and health, from the capacity to gain sustenance from land and the oceans, to the escalation and aggravation of infections and viruses [1]. During the last three decades, increased consideration has been given to the possible effects of climate change on human health. The numerous possible effects of worldwide climate change on human health can be separated into direct and indirect impacts, corresponding to whether they arise primarily via the effects of climate variables upon human biology, or are facilitated by climate-stimulated alterations in other organic and biogeochemical structures [2]. Developing climate-resilient health systems—which

include climate sensitive disease surveillance, governance, human and institutional capacity, and climate resilient health policies and plans—is increasingly seen to be vital [1,3]. By adopting a rapid assessment and response (RAR) methodology, which incorporates a healthcare workforce assessment of eight healthcare facilities in the Agincourt sub-district of Bushbuckridge in the Kruger to Canyons Biosphere Region in Mpumalanga, South Africa, this pilot study strives to assess the healthcare needs within the area given the existing and estimated effects of global and local climate change, and to advance practice and policy recommendations.

2. Background

According to the second Lancet Commission on Health and Climate Change, climate change is the most significant international health concern of this era [4]. Moreover, when climate change is considered from a health perspective, and not purely as a biophysical or economic concern, it is increasingly proposed that the human species is facing a dilemma that affects the core of civilization [5]. Climate change effects will be unevenly distributed; the economies and societies of low-and middle-income states are especially susceptible due to their relatively higher reliance on climate-sensitive resources and reserves compared to developed economies [1]. King [6] emphasises that many low-and middle-income states are demographically trapped, in that some communities have surpassed, or are predicted to surpass, the carrying capacity of their indigenous ecologies. Such barriers to sustainable development are evidenced by the impact of adverse climatic conditions on a population's susceptibility to communicable diseases, malnourishment, and famine. Climate change is predicted to exert further stress on already exploited ecologies [7]. Legislation, assets and responses to assist individuals and biophysical systems—especially those who are the most vulnerable—have been circumscribed in breadth and range [8].

The Climate and Health Alliance 2012 Climate Vulnerability Monitor estimates that the failure to take action on climate change will result in 400,000 related mortalities each year, increasing to 700,000 by 2030, and will cost US\$ 1.2 trillion [9]. To contextualise this, the World Health Organization (WHO) projects that there are 60,000 causalities associated with life-threatening weather events, 2.2 million diarrhoea-associated causalities, 80,000 malaria-associated causalities, and 3.5 million famine-associated causalities each year [10]. Furthermore, the emergence and reemergence of climate-related parasitic diseases in Africa, which may include the Ebola virus, is particularly concerning. Such diseases often not only directly compromise human health, but promote a positive feedback loop of impoverishment and financial inertia in vulnerable populations [11,12].

Climate change consequently poses a critical risk to human health and survival, and healthcare experts have a responsibility to campaign for advocacy at all ranks to alleviate climate change [13]. Nonetheless, the healthcare industry has been slow to observe the significance of climate change in the field of health [14]. To promote steps that could be taken to deal with climate change, the 2015 Lancet Commission on Health and Climate Change outlines nine propositions for consideration, one of which is the scaling up of expenditure for climate-resilient health systems globally [3]. Research on climate change and health in sub-Saharan Africa is hindered by limited access to data— particularly at a local scale with respect to both climate-determining factors and effects on health; the absence of a distinct theoretical causality model; a lack of a cohesive or multifaceted appraisal approach, together with an inadequate communication of intersectoral viewpoints, interdisciplinary involvement, and proficiency in public sectors and academia [15,16].

2.1. Climate Change and Health in Sub-Saharan Africa

Within the African context, many of the main challenges—such as the increase of HIV/AIDS, the influence of economic globalisation, natural catastrophes, and economic and geopolitical stresses—converge with climate change [17,18]. In South Africa, the consequences of climate change are likely to place increased pressure on the ability of the state to grapple with an already escalating range of medical illnesses that consumes significant civic and private sector healthcare capital [3].

AIDS, which has a considerable impact on structures of the healthcare systems, has taken a minimum of a million lives each year since 1998 in sub-Saharan Africa. A substantial number of these mortalities took place in South Africa, which holds the highest count of HIV-infected persons globally. In 2013, 6.3 million people were living with HIV and 330,000 were newly infected with the virus [19].

The South African government has commenced audits on the preparedness of health, associated services, and reserve responses to deal with the health impacts of climate change. Increased stress on the health sector as a consequence of climate change undermines the significance of health structure reinforcement, primary healthcare re-engineering and the implementation and expansion of the National Health Insurance (NHI) scheme [20]. Climate change actions, both mitigation and adaptation, will necessitate more effective intersectoral government policy, management, and intervention, together with inter and transdisciplinary investigations and initiatives. McMichael [17] (p.12) concisely states that “human health can—indeed should—be viewed as the real ‘bottom line’ of climate change”.

More explicit influences concerning climate change and health are being progressively examined in South Africa, concentrating on respiratory and cardiovascular illnesses, tuberculosis (TB), diarrhoea, and vector-borne communicable diseases such as malaria. Elevated and low temperatures, alongside variable rainfall and drought, have been demonstrated to affect death rates [21]. Human settlements in particular have been related to increased temperature-associated mortality [22]. For some associations, such as HIV/AIDS, existing empirical evidence upon which to base a risk assessment remains inadequate. A study by Talman, Bolton, and Walson [23] proposes that a syndemic exists between the HIV/AIDS epidemic and environmental degradation. While the investigation by Egondi et al. [24] alludes to a relationship between HIV/AIDS related mortalities and meteorological factors, but fails to discuss the relationship in any detail, focusing rather on the daily time-series trend of all-cause mortality patterns in relation to climate indicators.

2.2. Human Resources in Health

Roughly half of the global population can access only a fourth of the world’s medical practitioners [25]. This discrepancy is most distinct in under-resourced locations [26–30]. In South Africa, a discriminatory dispersal of healthcare amenities is evident [31], and underprivileged groups, which are estimated to constitute just over half of the population, have access to only 12% of the nation’s medical practitioners [32,33]. Most South African medical practitioners (70%) work privately, leaving fewer than 11,000 practitioners to attend to the majority of the population who only have access to state healthcare assistance [34]. There is a mean of 13 medical doctors and 2 specialist doctors available per 100,000 persons in the country’s rural regions [35]. These inequalities are intensified when medical care access is more challenging and expensive, and where transportation expenses are high [36]. With an insufficiently skilled workforce, health provision is weakened, and the lack of adequate wellness markers hinder the ability to reach sustainable development goals. Generating sustainable means for drawing and keeping healthcare professionals in under-serviced populations is a difficult task [37].

2.3. Health and Environmental Study Findings in Agincourt, South Africa

Between 1992 and 2011, an aggregate of 12,209 mortalities were recorded over 1,436,195 person-years, providing a mean death rate of 8.5 per 1000 person-years in Agincourt, a sub-district of Bushbuckridge in which this study was located. Within the 20-year timeframe, the community experienced a significant HIV epidemic, which led to a doubling of the death rate. Recent declines in death rates are due to mother-to-child HIV transmission prevention programmes and stabilising fertility rates; however, levels remain above the 1992 baseline recorded by the Health and Demographic Surveillance System (HDSS). The population decreased from 545,822 to 500,128 between 1996 and 2001, and then increased to 541,248 in 2011 [38,39]. There are indications of a heightened risk of cardio-metabolic illness across the lifespan [40]. Premature growth restriction, or stunting, in one-third of one-year-olds has been observed [41]. According to a recent study undertaken in Agincourt, malaria mortality could not be unambiguously associated with overall temperature trends, though it may be a contributory factor [42].

No other studies concerning changes in climate and health or morality indicators have been conducted in the Agincourt sub-district yet. Furthermore, Byass et al. [43] propose that malaria may be the most dominant researched mortality issue in Africa in relation to climate thus far, but not necessarily the most significant one.

Most households in Bushbuckridge are reliant on local biophysical resources for daily sustenance, such as forage for livestock, fuelwood, wild foodstuffs, roofing grass, wood for building and other household commodities. These supplies are utilised for both domestic use and for generating revenue [44]. Fuelwood is the leading supply of energy consumed by most settlement homes in South Africa to sustain everyday household energy needs. As there are restricted economic means, most of the households are not able to access electricity, and continue to rely on locally sourced fuelwood as a supply of inexpensive energy [45]. Food insecurity among impoverished household is an ongoing concern, and self-sustenance via harvesting natural resources is an important contingency during stressful periods, such as the demise of a breadwinner [46]. In the most impoverished homes, dependence on indigenous reserves is heightened [47]. Similarly, there are considerable disparities in the degrees of sustenance safeguards amongst families that have lost an adult and those who have not [48]. There is an increased degree of dependence on wild foodstuffs; for example, most households rely on wild spinach on a weekly basis, though families that make nutritional use of wild foods do not necessarily experience heightened food security. Overall, food security is lower amongst families experiencing a peak-age adult death. Death-afflicted households are also more prone to rely on indigenous commodities such as insects, fruit, and fuelwood as money-saving substitutes [49].

2.4. Significance and Limitations in the Field

McMichael [17] has singled out that climate change does not raise completely new concerns with regards to the burden of disease, or requirements on the capability of healthcare structures to tackle these illnesses. Climate change is expected though to intensify existing vulnerabilities. The primary burden of disease in South Africa is communicable diseases (HIV/AIDS and TB), intended and unintended injury, chronic illnesses, and maternal and infant death [50]. The present distribution of the burden of disease in South Africa, particularly HIV/AIDS in the identified field sites, is a helpful beginning point for deliberating on the probable significance of climate change effects [51]. Constraints to climate change and health research in South Africa include restricted formalistic backing for interdisciplinary introspection and studies, programme advancement, and intersectoral policy [20].

3. Materials and Methods

A RAR methodology is used to gain a more integrated exploration of the study area by examining previous studies conducted in the biosphere, by mapping healthcare facilities and service providers, and by undertaking a facility infrastructure and workforce capacity investigation by means of key informant (KI) interviews. The RAR method was originally developed by the University of London for WHO and UNAIDS [52–56]—and is specifically appropriate for exploring difficulties within public health without resorting to ‘unscientific’ conjecture; it simultaneously assimilates data for tangible intervention planning; and within the context of this study has been adapted to explore sustainable healthcare service capacities against the backdrop of climate change [57]. The methodology has been verified widely in low- and middle-income countries since 1997 [57].

For suitable health promotion interventions in the field of climate change and health adaptation strategies, the requirement to have knowledge of the complete number of individuals involved or affected by particular threatening situations is not necessary. It is adequate to have an understanding that a considerable number of individuals are affected, or potentially affected. RAR is consequently used in circumstances where the emphasis is on knowledge that renders a rapid integrated response possible for complex health-related problems [57,58].

Emphasis was placed on stakeholder involvement in the conceptualisation and implementation of the study. To facilitate this, networking was conducted with the Provincial Department of Health

in Mpumalanga, the South African Medical Research Council and University of the Witwatersrand (MRC/Wits) Agincourt Unit (Wits Agincourt), and the South African Weather Services, as well as with local non-governmental organisations (NGOs) in the area, namely Buffelshoek Trust and Kruger2canyons (K2C). The principal investigator (PI) met with stakeholders in the Agincourt area on two separate occasions in order to obtain local inputs and insights. In the first meeting, the PI attended a day seminar hosted by Wits Agincourt at the Wits Rural Facility in Agincourt, where the project was presented and discussed with approximately 50 attendees from the scientific community, the Provincial Department of Health in Mpumalanga, community leaders, NGOs in the area (Buffelshoek Trust and K2C), and a private game reserve (Sabi Sabi). On the second occasion, the PI and Africa Health Placements met with two members from Wits Agincourt and one member from the Provincial Department of Health in Mpumalanga, also at the Wits Rural Facility, in order to plan for the implementation of the healthcare workforce assessment and to discuss sourcing mortality data from Wits Agincourt. Networking was also undertaken with the South African Weather Services and the Council for Scientific Industrial Research (CSIR) within the broader context of this initiative. The University of South Africa formally partnered with Africa Health Placements to implement the study. The PI trained two Africa Health Placements staff in the methodology, which included the core principles of the RAR methodology as set out in the Trimbos Institute's RAR training manual, the interview approach and survey to be used, as well as ethical considerations. Africa Health Placements is an NGO located in South Africa that strives to support, enhance and provide equitable healthcare systems in Africa. Focus group sessions were not held with KI staff participants due to capacity shortages in the healthcare facilities. A seminar was held in October 2018 to disseminate findings from the study, so as to develop partnerships across the network, and to highlight key areas that need further development from a policy, implementation and research perspective. Invitees and attendees included representatives from the University of South Africa, Africa Health Placements, the Foundation for Professional Development (a private institute of higher education affiliated to the South African Medical Association), the International Training and Education Center for Health (I-Tech), the South African National Department of Health, the South African Weather Services, the CSIR, the Massachusetts Institute of Technology's (MIT) Climate CoLab (MIT Sloan School of Management), and the French Embassy in South Africa.

3.1. Research Objective

Within the context of climate change effects on public health systems, the study aims to identify shortages of clinical skills and services in the identified human settlements, aligning in varying degrees to the 3rd, 11th, and 13th Sustainable Development Goals 2015–2030 of the United Nations [59], namely to safeguard healthy lives and advance health for everyone at all ages; to ensure that cities and human settlements are inclusive, protected, resilient, and sustainable; and lastly, to embark on crucial action to tackle climate change and its effects.

3.2. Case Study Setting

The Kruger to Canyons Biosphere Region, established by UNESCO in 2001, incorporates the Bushbuckridge municipality and Agincourt sub-district [60]. The location encompasses the Kruger National Park and the Blyde River Canyon, two key tourism sites, and is situated in the northeastern region of South Africa. The present borders stretch north from the Letaba River to the Sabie River in the south, and west to the Blyde Escarpment to the Mozambique border in the east (see Figure 1). Vast stretches are designated as conservation territories. The grasslands in the Great Escarpment Mountains (Drakensberg) and afro-montane forests overlook the savannah bushveld of the Lowveld, while the water catchment receives higher rainfall in the Great Escarpment Mountains and connects these three biomes via rivers flowing to the Indian Ocean. It has a population of approximately 541,248, of which 99.35% are black African. The majority of the population in the region lives in poverty, under poor housing conditions and do not have access to private medical care [60].

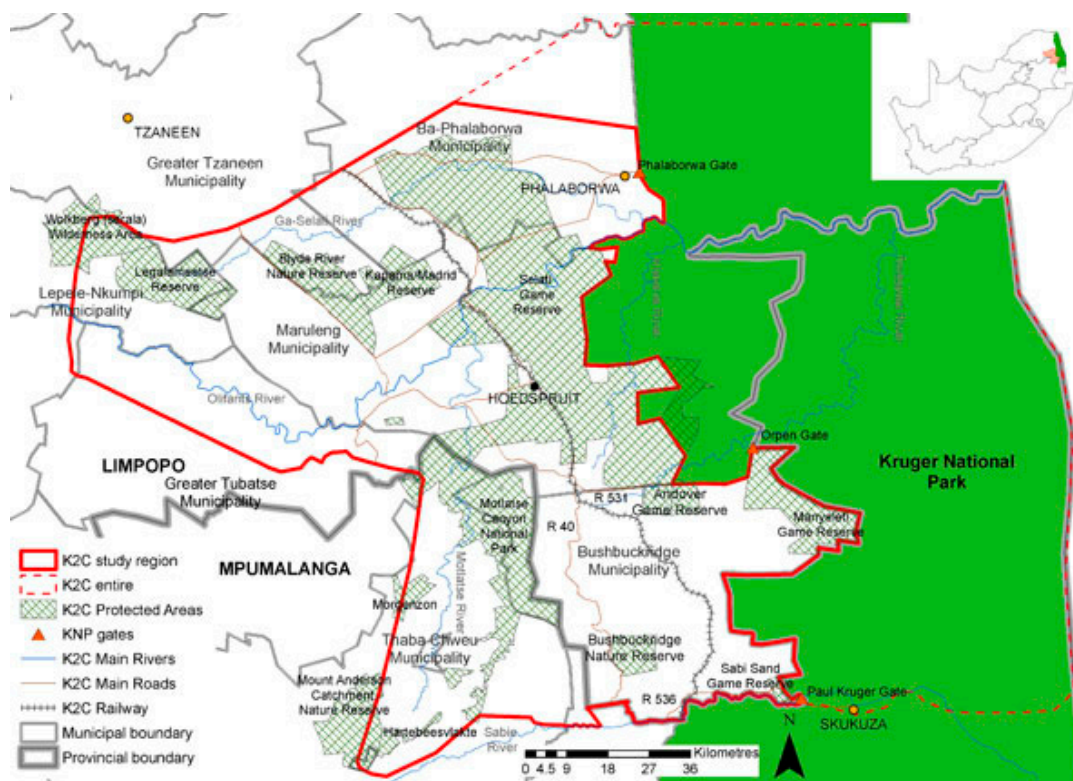


Figure 1. K2C Biosphere location in South Africa. Source: <https://www.wits.ac.za/gci/featured-research/global-change-land-cover-change--biodiversity-conservation/>.

3.3. Data Sources

There are ten healthcare facilities in the Agincourt sub-district. Africa Health Placements sourced healthcare facility workforce assessment data from eight KI survey interviews with healthcare facility staff. KI interviewees were selected on the basis of their seniority and in-depth knowledge of their respective healthcare facility and workforce needs. Six facilities are classified as public healthcare clinics (PHCs) (Belfast, Cunninghammore, Justicia, Kildare, Lillydale, and Xanthia), while two facilities are classified as community healthcare clinics (CHCs) (Agincourt and Bhubezi (not indicated on the figure) (see Figure 2 below). Access to two PHCs in the vicinity, namely Rholana and Ireagh, was not possible due to gatekeeping constraints. Community healthcare clinics, which are also state-run facilities, generally offer a greater range of services when compared to PHCs facilities, normally operating for 24 h (as opposed to 8 h) and often have in-patient facilities.

The semi-structured KI interviews were based on a structured questionnaire developed by Africa Health Placements, which assesses services offered, workforce capacity, and facility location and infrastructure. The following domains were assessed to structure and to organise the healthcare workforce investigation: hospital location information; patient/disease burden; referral location; clinical services offered; current staff capacity; and training and supervision. General knowledge concerning climate change associations with health was explored through the open-ended question “Is there anything else you could like to add?”, and by asking all KI respondents “What, if any, impact have you noticed on your clients’ health due to climate change?”, followed by interviewer probes. All raw data was recorded on a laptop during the interviews and transferred to an Excel spreadsheet.

The investigation is helpful in determining the nature and needs relating to healthcare and climate in the area and aspires to inform integrated responses for problems the facilities and communities may be facing.

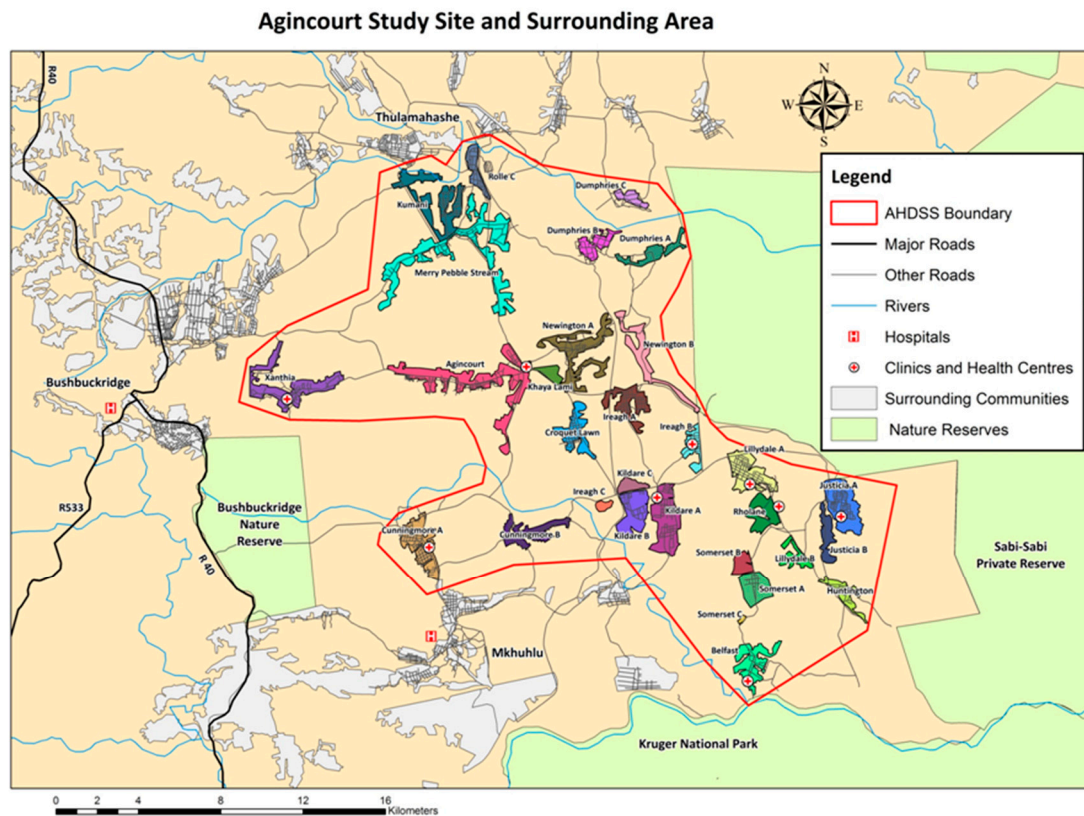


Figure 2. Agincourt mortality and healthcare facility workforce data sources. Source: <http://www.agincourt.co.za/index.php/about/maps/>.

3.4. Data Analysis

The data was interpreted by means of thematic content analysis. This technique has proven to be beneficial in the formulation of healthcare policy and interventions. Coding is applied in the disaggregation and investigation of central themes. The process of investigation during data analysis involves linking coded categories and concepts to one another through both inductive and deductive reasoning [61,62]. Categories are established by eliminating the constellation of words or statements that relate to the same central meaning, also referred to as meaning units, from the open-ended questions. The derived categories, such as medication delivery times, barriers to service delivery, and climate impacts on health, were then coded in order to detect the regular patterns. Themes were derived from categories that are classed together. To validate analyses, study findings were discussed with a subdivision of KIs and stakeholders for the enhancement and corroboration of analyses [61,62].

3.5. Ethical Considerations

This study is low-risk, as it relies on healthcare and workforce interview and survey data that has been anonymised. No study outcomes are attributed to a specific clinic. Technical shortcomings are outlined, constraints of the investigation and methodological limitations that impact on the validity of the study are also detailed [61]. Research ethical approval was received from the University of Oxford Central University Research Ethics Committee (ref. no. SSD/CUREC1A/EQ C1A 16-03) in January 2016 and the Provincial Department of Health in Mpumalanga, South Africa (ref. no. MP_2015RP14_637) in November 2015.

3.6. Study Limitations

A limitation of this study is that it was implemented in only one sub-district, so it may not be generalisable to other areas of South Africa. Furthermore, due to staff capacity shortages at the

respective facilities that participated, only one staff member could be interviewed at each facility. Due to the capacity constraints it was also not possible to conduct focus groups sessions with staff. Not interviewing patients is also indicated as a study limitation. The workforce questionnaire developed and standardised by Africa Health Placements is not specific to the assessment climate change, however, it provides a reliable indication of what the systemic healthcare needs are within under-resourced contexts and could thus be contextualised within the present and future scenario of climate change systemic effects on the public healthcare industry. Notwithstanding the barriers highlighted, the facility workforce assessments were conducted in 8 out of the 10 facilities in the sub-district, and the standardised questionnaire was utilised in all of the facilities, which allows for reliable comparison across the facilities.

4. Results

4.1. Facility, Infrastructure, and Accessibility Factors

Data was analysed from eight KI healthcare facility staff survey interviews, namely three acting charge sisters (two PHCs and one CHC), one charge sister (PHC), two professional nurses (two PHCs), one deputy charge sister (PHC), and one technical assistance manager (CHC)). The catchment population in the area ranges between 9900 and 11,900 individuals. No patient is ever turned away from any of the facilities, and the average patient waiting time for assistance varies between 30 min and 2 h. All PHCs operate for eight hours per day, every day of the week, with patient headcounts per month for each facility fluctuating between 2000 and 5400 (see Table 1 below).

Table 1. Facility, infrastructure, and accessibility factors.

Facility	No. of Hours Open	No. of Days Open per Week	Catchment Population	Total Patient Headcount per Month	Adequate Patient Seating	Planned Patient Transport	Facility has Own Entrance	Accessable by a Good Road Infrastructure	Facility has Running Water	Closest Airport	Computer/IT Access	Secure Patient Filing System
* PHC1	8	7	11,821	3202–3365	No	No	No, via casualty	Yes	Yes	Kruger MP Int. Airport	Yes	Yes
* PHC2	8	7	13,270	2956–3134	No	No	No, via casualty	No	Yes	Kruger MP Int. Airport	Yes	Yes
* PHC3	8	7	9967	2436–2704	No	No	No, via casualty	No	Yes	Kruger MP Int. Airport	Yes	No
* PHC4	8	7	9958	2178–2519	Yes	No	No, via casualty	Yes	Yes	Kruger MP Int. Airport	Yes	Yes
* PHC5	8	7	Unknown	2098–2173	No	No	No, via casualty	No	Yes	Kruger MP Int. Airport	Yes	Yes
* PHC6	8	7	Unknown	2084–2171	No	No	No, via casualty	No, need 4 × 4	No	Kruger MP Int. Airport	Yes	No
** CHC1	24	7	Unknown	4200–5400	Yes	No	No	Yes	Yes	Kruger MP Int. Airport	Yes	Yes
** CHC2	8	7	Unknown	2000–3050	Yes	No	No	No	Yes	Kruger MP Int. Airport	Yes	Yes

* PHC—public healthcare clinic; ** CHC—community healthcare clinic.

Five KI PHC respondents recount that there is insufficient seating for patients, where sufficient seating was regarded as a chair or bench for each patient to sit on. None of the facilities have planned patient transport available; patients generally have to rely on the informal taxi sector. Furthermore, none of the facilities have their own entrances, which would have made them more easily accessible to patients, though PHCs are integrated with casualty divisions. Three PHCs are accessible via good road infrastructure, while two have substandard roads, and one facility is only accessible by means of 4×4 vehicles. One PHC facility reported not having access to running water. The closest airport is the Kruger Mpumalanga International Airport. Half of the PHCs opening times reportedly do not meet the needs of the community due to an insufficient number of full-time staff, while both CHCs are of the view that their opening times are sufficient in relation to the communities' needs (see Table 1 above).

4.2. Cross-Referrals and Professional Support

Table 2 below specifies the support structures available to the healthcare facilities. Five PHCs are supported by the Matikwane Hospital and one PHC is supported by the Mapulane District Hospital. For the most part, referral to the relevant district hospital is straightforward. Three PHCs refer to CHCs with relative ease, while the remaining three PHCs do not refer due to any doctors being there and the distances involved. The CHCs support five PHCs in the area (Xanthia, Justicia, Lillydale, Kildare, and Cunningmore) with referrals taking place fairly easily. Four PHCs indicate that they have easy telephonic access to doctors. One CHC recounts that telephonic assistance from a doctor is rare because doctors are overloaded (this facility is open for 24 h a day). All PHCs have access to laboratory services at Matikwane Hospital through the National Healthcare Laboratory Services (NHLS), while the CHCs offer laboratory services. In terms of support from district and provincial health management, three PHCs state that support is always reliable.

Table 2. Cross referrals and professional support.

Facility	District Hospital Support	Easy Referral to District Hospital	Easy Referral to CHC	Telephonic Access to Doctors	Laboratory Services	Reliability of District and Provincial Management Support
PHC1	Yes, Matikwane	Mostly	No	Mostly	Yes (Matikwane NHLS)	Mostly
PHC2	Yes, Matikwane	Yes	No	Yes	Yes (Matikwane NHLS)	Yes
PHC3	Yes, Matikwane	Yes	Yes	Yes	Yes (Matikwane NHLS)	Yes
PHC4	Yes, Matikwane	Mostly	No	Sometimes	Yes (Matikwane NHLS)	Mostly
PHC5	Yes, Matikwane	Mostly	Mostly	Yes	Yes (Matikwane NHLS)	Yes
PHC6	Yes, Mapulane	Mostly	Mostly	Yes	Yes (Matikwane NHLS)	Mostly
CHC1	N/A	Mostly	N/A	Rarely	Yes	Mostly
CHC2	N/A	Mostly	N/A	Yes	Yes	Mostly

4.3. Professional Staff Component

The number of full-time professional nurses (PNs) at PHCs ranges from four to six, with average consulting times ranging between 15–30 min. One CHC has 16 PNs, while the other has six, with patient consulting times averaging at 10 min for both facilities (see Table 3).

Regarding the number of full-time enrolled nurses (ENs) at the facilities, four PHCs have two ENs, one PHC indicates five ENs, and one PHC employs four. CHC1 employs four ENs, and CHC2 employs one. The ENs consulting time with patients averages to approximately 5 min across all the facilities. There are relatively few enrolled nursing assistants (ENAs) across the facilities; two PHCs have one ENA each, while the remaining none. The CHCs have respectively two and one ENAs. Similar to the other nursing professionals, the average consulting time per patient is 5 min (refer to Table 3 below). Patient follow-up appointments are made at all of the facilities.

Table 3. Professional staff component.

Facility	No. of Professional Nurses (PN) & Time Spent Consulting	No. of Enrolled Nurses (EN) & Time Spent Consulting	No. of Enrolled Nursing Assistants (ENA) & Time Spent Consulting	No. of Consulting/Sessional Medical Doctors & Time Spent Consulting	CEO/Facility Manager	No. of Data Capturers (Full-Time)	No. of Administrative Officers (Full-Time)	No. of Physio-Therapists (Sessional)	No. of Occupational Therapists (Sessional/Full-Time)	No. of Speech and Hearing Therapists (Sessional)
PHC1	5 20 min	2 5 min	1 5 min	1 consulting 15 min	1 PN	1	1	1	1 sessional	0
PHC2	6 17.5 min	2 5 min	1 5 min	1 consulting 20 min	1 PN	1	0	1	0	0
PHC3	6 15 min	2 4 min	0 0 min	1 consulting 10 min	0	1	0	1	1 sessional	1
PHC4	6 22.5min	5 12.5 min	0 0 min	0 0 min	0	1	0	1	0	0
PHC5	5 10 min	4 7.5 min	0 0 min	0 0 min	0	1	0	2	2 (1 sessional & 1 full-time)	0
PHC6	4 30 min	2 5 min	0 0 min	0 0 min	0	1	0	0	0	0
CHC1	16 10 min	4 50 min	2 7 min	2 sessional 15 min	1 PN	1	3	0	0	0
CHC2	6 10 min	1 5 min	1 5 min	2 full-time 1 consulting 15–20 min	1 PN	3	4	0	0	0

Three PHCs have one consulting medical doctor (MD) each. The remaining PHCs have no access to consulting MDs. CHC1 has one sessional MD, and CHC2 employs two. The average patient consulting times for MDs across the sites is between 15 to 20 min (see Table 3 above).

Four PHCs have access to one sessional physiotherapist, while one PHC facility has access to two physiotherapists. The CHCs have no access to sessional physiotherapists according to the KI interviewees. Two PHCs (PHC1 and PHC3) have access to one sessional occupational therapist that consults once a month, while PHC5 indicates access to one sessional occupational therapist and one full-time occupational therapist. The CHCs do not have access to any occupational therapists. Only one facility (PHC3) has access to one sessional speech and hearing therapist who visits the facility once a month (see Table 3 above).

None of the facilities have a full-time pharmacist or basic pharmacist's assistant, apart from CHC2, which has access to one full-time pharmacist and one full-time basic pharmacist assistant. Furthermore, only PHC4 reports access to a full-time social worker, while CHC1 employs two full-time social workers (refer to Table 4 below). It should be noted that none of the facilities employ medical specialists, dentists, dieticians, or psychologists.

Table 4. Professional staff component.

Facility	No. of Pharmacists (Full-Time/Sessional)	No. of Basic Pharmacist Assistants (Full-Time)	No. of Social Workers (Full-Time/Sessional)	No. of Environmental Health Practitioners (Sessional)	Outreach Health Promoters (Sessional)	No. of Community Outreach Workers (Home Based Carers) (Full-Time)	No. of Community Liason Officers (Full-Time)	No. of HCT Counsellors (Full-Time/Sessional)	No. of Cleaners (Full-Time)	No. of Security Guards (Full-Time)
PHC1	0	0	0	1	0	12	0	1	2	6
PHC2	0	0	0	1	0	20	0	2	2	6
PHC3	0	0	0	1	0	23	0	3	1	6
PHC4	0	0	1 full-time	0	0	29	0	2	2	6
PHC5	0	0	0	1	1	unknown	24	2	2	6
PHC6	0	0	0	0	1	unknown	0	2	2	6
CHC1	0	0	2 full-time	1	0	20	0	4	3	6
CHC2	1 full-time	1 full-time	0	0	0	unknown	0	6	1	4

Table 4 above further indicates that four PHCs and CHC1 have access to environmental health practitioners who visit the facilities once every four months. One PHC has access to an outreach health promoter on a quarterly basis, while two PHCs indicate access to outreach health promoters who visit the facilities once a month. Neither CHCs makes use of outreach health promoters. Regarding the number of community outreach community healthcare workers who operate as home based carers: PHC1 has 12, PHC2 has 20, PHC3 has 23, PHC4 has 29, and PHC5 and PHC6's number of home-based carers remains unknown. CHC1 reports making use of 20 community outreach community healthcare works, while the numbers at CHC2 remains unknown. Only one facility, PHC5, reports making use of community liaison officers (24 in total). Concerning the number of HIV counselling and testing (HCT) counsellors employed full-time at PHCs, one facility has one, four facilities have two, and one facility has three. CHC1 employs four HCT counsellors, while CHC2 employs six. Cleaners work full-time at all of the facilities. All the PHCs and CHC1 have six security guards who work 12-hour shifts, 7 days a week, while CHC2 employs four security guards who work 12-hour shifts, 5 days a week (see Table 4 above).

4.4. Services Offered

All the PHCs offer the following services: preventative and curative healthcare for children under five, antenatal and postnatal care, reproductive healthcare, screening for cervical cancer, acute curative intervention for adults, treatment for sexually transmitted diseases, TB treatment services, chronic disease care, rehabilitation services, and mental healthcare. Furthermore, all the PHCs refer for aspects related to violence, sexual, and other abuse; ophthalmic services; radiology services; and oral health services. Three PHCs offer occupational health services, two PHCs do not and one PHC refers for such services. None of the PHCs offer youth-friendly services according to the National Adolescent Friendly Clinic Initiative (NAFCI) guidelines [63].

Both CHCs offer the following services: antenatal care, screening for cervical cancer, acute curative care for adults, violence and (sexual) abuse care, treatment for sexually infected individuals, TB services, and chronic disease care. Preventative and curative healthcare for children under five, postnatal care, reproductive healthcare and youth-friendly services (NAFCI guidelines) are offered at CHC1. The same facility also refers patients for the following services: rehabilitation, mental healthcare, oral health services, ophthalmic services, radiology, and occupational health.

The average ambulance arrival time ranges from one to three hours across PHCs. CHC1's ambulance arrival time can take up to three hours, while CHC2's arrival time is almost immediate. The reason for the discrepancies between the respective facility ambulance arrival times remains unknown and necessitates further enquiry. The pharmacies at all of the PHCs operate every day of the week for eight hours, and the professional nurses are responsible for ordering the medication—with a delivery time that ranges from one to two weeks. The medication stock availability ranges from 70% to 90% at PHCs. Across PHCs, HIV is the most common condition that medication is dispensed for, followed by diabetes and hypertension. CHC1's pharmacy operates every day of the week for 24 h, while CHC2's pharmacy is open from Mondays to Fridays for eight hours a day. Medication delivery can take up to a week, and stock availability at both facilities is approximately 95%, while medication for HIV, TB, and hypertension is the most needed at CHC facilities. Laboratory pickup services are offered at both CHC facilities.

4.5. Training Opportunities

Generic healthcare, counselling and managerial training opportunities are available at all of the facilities, particularly for staff who wish to progress from ENs to PNs at PHCs. At CHCs, training is mostly available for nursing specialists, ENs and counsellors. Daily supervision from managers is also available at all facilities, and monthly supervision from sub-district managers. Staff is also performance managed every three months at all facilities, and five PHCs and one CHC staff interviewed

felt that there are opportunities for professional growth. No PNs are trained in medication dispensing, emergency care, and paediatrics.

4.6. Staff Shortages and Human Resources Needs

Four KI PHC and two KI CHC interviewees state that staff shortages negatively impact values and attitudes in health facilities. One KI PHC respondent indicates that patient safety and reliable medical care are compromised by staff shortages. All of the respondents replied that support from the district and the sub-district has been consistent.

The three greatest challenges to service delivery in the facilities are: (1) staff shortages (all of the interviewee responses); (2) insufficient equipment and supplies (six PHC responses and one CHC response), for example, a lack of ear, nose and throat examination sets at one PHC, a lack of equipment needed for oxygen machines at one CHC, and a broken sterilising machine at two PHCs; (3) infrastructure problems (three PHC responses), for example, a lack of space for isolating TB patients and no air-conditioners (sometimes patients faint due to the heat); and finally (4) cleanliness and infection control were reported as problematic at two PHC facilities. No running water was cited at one PHC, which also compromises the working of toilets. Overall, staff retention was not regarded as problematic by KIs at most of the PHCs, however, one KI PHC respondent indicates that working conditions lead to the loss of staff, while another KI CHC facility respondent cites remuneration as a reason for staff turnover.

4.7. Perceived Effects of Changes in Climate at a Healthcare Facility Level

The participants did not focus extensively on aspects related to climate change, an aspect we deliberate on in the Section 5, though they were asked for their views regarding the perceived effects of climate change on health. From six KI PHC interviews, one KI respondent states that he/she did not perceive a change in conditions that were being presented at the facility as a result of changes in climate. Heat rash is prevalent in babies, but some adults also present with this condition according to four PHC respondents. The incidence of fever has been on the increase and influenza is common due to fluctuations in temperature (cited by two PHC respondents). One KI PHC respondent recounts hypertension patients who had trouble breathing and thus collapse. Furthermore, one KI PHC respondent reports diarrhoea and heatstroke. CHC KI interviewees cite influenza, diarrhoea, heatstroke, heat rash, and fever as health effects of climate change.

5. Discussion

As outlined in South Africa's Intended Nationally Determined Contribution (INDC), climate change is already having an effect in South Africa, with clear heightened temperature, rainfall fluctuations and rising sea levels. The INDC and the Intergovernmental Panel on Climate Change (IPCC) reports further note that if global average temperatures rise to 2 °C above pre-industrial times, this translates to up to 4 °C for South Africa by the end of the century. Policies and interventions need to respond quickly and effectively so that the country's aspirational goals on adaptation in the healthcare industry may be met [64,65]. South Africa's National Development Plan (NDP) further states that South Africa's public healthcare system cannot meet demand or sustain quality [66]. The study outcomes overall support this assertion, indicating that generally the facilities in the Agincourt sub-district fail to meet the minimum service delivery requirements. There is a significant gap in terms of access to medical officers and qualified pharmacy personnel; for example, three PHCs have no access to a sessional medical doctor. There is also a lack of social workers and other para-medical professionals across the sites. Seven facilities (six PHCs and one CHC) have no access to qualified pharmacy staff such as pharmacists and pharmacy assistants. Overall, the greatest human resource gap across the fieldsite facilities is with respect to pharmacy staff. A shortage of nurse specialists is evident in general, and a deficiency of professional nurses with dispensing licences at PHC settings, which is concerning due to the lack of access to qualified pharmacy staff available. Overall, the shortage of staff

is consistently identified as a critical inhibiting factor to delivering on the National Core Standards for Health Establishments in South Africa across all the sites [67]. No professional nurses have been trained in emergency or paediatric care. These findings are of concern since such professionals will be well positioned to raise understanding about climate change and health during conversations with patients, and to treat patients who may increasingly require medical attention due to the direct and indirect impacts of a changing climate.

Based on the analyses, five facilities are identified as requiring the most urgent human resources intervention, though the most constrained facilities tend to be clustered together, referring patients back and forth between one another. The most constrained facilities tend to be within each other's referral network (see Figure 3 below). They need additional health workers to ease bottlenecks, and a recommendation is made that they could recruit new skills or assign outreach workers from better-resourced facilities to alleviate the patient burden in overburdened ones.

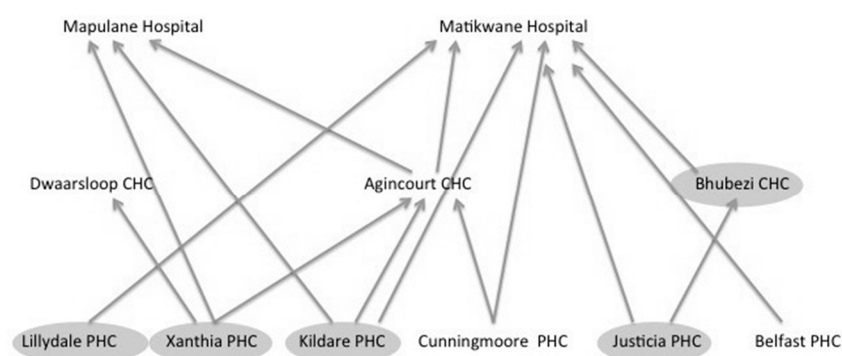


Figure 3. Cross-referral in most constrained clinics.

Generally, shortages in healthcare workers are related to the communities' failure to enlist, deploy, and retain employees in facilities that encounter the most hardship. Numerous considerations, including heightened service requirements owing to rapid population growth, an elevated incidence of HIV/AIDS, labour force attrition as a result of heightened HIV/AIDS incidence amongst healthcare employees, the migration of highly trained healthcare employees and operational circumstances that create inadequate enticement to draw and to retain capable employees, may exacerbate this problem [32,33]. Additionally, the number of qualified healthcare practitioners is static or decreasing as a result of inadequate financing. Overall, the skills combination is often insufficient to tackle present health and welfare requirements. Research findings suggest that healthcare practitioners who do stay in the system are frequently inadequately qualified and battle to cope with the heightened difficulty of overseeing patients on protracted chronic medical care, or to deal with climate-associated illnesses such as an epidemic of vector-borne infections [34].

Only three facilities are accessible via a good road infrastructure, and none of the facilities have planned patient transport available—as most patients are impoverished, transport is an additional financial burden. Although there is an airport in the area, the community is unlikely to make much use of it due to the associated high costs. The airport appears to mainly service the tourism industry, working professionals and the more affluent towns in the Kruger to Canyons biosphere. One PHC does not have access to running water, which poses a serious health concern. Half of the PHC opening times do not meet the needs of the community.

Since it is predicted that climate change will further exacerbate the burden of disease, facilities are likely to experience additional pressure. Verbal autopsy data sourced from Wits Agincourt indicates that there were a total of 13,799 mortalities in the Agincourt sub-district from 1992 to 2013. HIV is the most prevalent cause of death (2740), followed by TB (2282) and pneumonia (1117). There were also 282 diarrhoeal disease deaths, 338 respiratory neoplasm (cancer) mortalities, 390 digestive neoplasm deaths, 456 deaths caused by strokes, 290 unspecified cardiac disease deaths, 309 asthma mortalities,

and 117 neonatal pneumonia deaths. Relatively few deaths from malaria (180) and severe malnutrition (63) are recorded for this time period.

It is likely that, in a warmer climate, heavy rainfall will increase and be followed by fewer more intense events, a phenomenon that was verbalised by persons living in the area when the primary investigator visited the sub-district. This could lead to longer dry spells and a higher risk of floods [68]. A study by Diaz, Linares and Tobías's [69] highlights the significant effects of extreme temperatures on daily mortality among those aged 45–64, while Gasparrini and Armstrong's [70] study suggests that heat waves lasting more than four days pose the most significant mortality risk. Furthermore, elevated temperatures have been reported to heighten immunity to TB in the southern areas of South Africa, and conversely a drop in temperature increases susceptibility to TB death [71]. A decrease in minimum temperature has also been related to pneumonia contraction and mortality [72]. Tinling et al. [73] note that climate change has the potential to influence cancer development by directly and indirectly altering vulnerability patterns, however, more detailed studies are needed to assess the intricacies of this association. Higher incidences of stroke, unspecified cardiac and asthma mortalities have all been associated with a drop in minimum temperature [74–77]. Strokes have also been associated with a decrease in pressure, findings of which are supported in numerous meta-analytical studies [78,79], while asthma disease has been associated with a decrease in pressure [80]. Within the African context, diarrhoeal morbidity and mortality is associated with rainfall [81].

The mortality data over the 21-year time period in the Agincourt sub-district indicates that there is relatively little mortality related to malaria (180 deaths) in the area within the given time-frame. The Agincourt sub-district is classified as a low-transmission malaria area in South Africa, though, as indicated earlier in the paper, there may be relationship between malaria mortality and temperature [43]. Peterson [82] notes that malaria vector spread and contamination may be altering due to climate change and global warming, he proposes no general rise in malaria occurrences for Southern Africa, but rather a move of vectors and malaria contamination due to climate effects. The distribution of malaria is also strongly influenced by the use of pesticides, the availability of vaccination, and the emergence of drug resistance in the *Plasmodium falciparum* parasite. Hence, the extent of any increase in malaria risk due to climate change will be superimposed on the variation in malaria spread related to socio-economic growth, population increases and the effectiveness of control measures [1]. Furthermore, the relatively low number of mortalities in Agincourt due to severe malnutrition (63) may imply that the communities' reliance on wild foodstuffs on a weekly basis, such as wild spinach [49] has not (yet) been affected by variations in climate, though there are reports of stunting in a third of one-year-olds [41]. These literature findings, together with the available mortality data in Agincourt, highlight the critical need for extended studies on mortality and meteorological measures that are specific to the Agincourt sub-district. Once such information is, healthcare services will have a better indication of what diseases and intervention measures to plan for now and under a future of climate change. There is also a need to develop a climate change and health specific workforce tool that can be implemented in under-resourced healthcare facilities.

Furthermore, staff do not have access to climate change, sustainability and health (care) educational and training programmes. There is limited knowledge amongst the facility respondents with regard to current and future associations between climate change and health. The capacity of the facilities to plan for climate-associated consequences appears to be limited, given the immediate necessity to concentrate on everyday, urgent healthcare provision. The study outcomes highlight the need to train healthcare facility staff on aspects related to climate change, health, and sustainability. In a study undertaken in Pakistan, knowledge, education, access to healthcare facilities, and policies directed at increasing the healthcare workforce played a significant role in adapting to heat waves [83]. Lastly, environmental health practitioners, who are employed at several facilities and have traditionally played a significant role in implementing environmental health services to communities, would benefit from training in climate change and healthcare interventions, and being incorporated in grassroots community climate adaptation strategies [84].

6. Conclusions

There are numerous obstacles to attaining public healthcare sustainability within the developing context. These obstacles are multifaceted, exceedingly interwoven, serious, and—some believe—overwhelming [85,86]. Health service studies remain a generally marginalised domain of investigation [86]. Sustainable strategies need to meet human needs, ensure social justice, and respect ecological limits [87,88]. The IPCC notes that fast-tracking public healthcare interventions to decrease the current burden of illnesses, especially illnesses in low- and middle-income states associated with climate change and variation, is the single greatest action that can be taken to diminish related negative health effects. A review of the climate change literature indicates that there have been few studies on regional impacts, and further research in the Agincourt sub-district can provide an important contribution.

This study shows that challenges remain evident in the current provision of health services. A dearth of healthcare workers persists in vulnerable communities, and facility infrastructure problems persist. Work undertaken to prevent the current migration of healthcare workers from South Africa, and the recruitment of foreign medical personnel to South Africa would benefit from government and private support where needed. In addition to enhanced funding, clear assessment of where health workers with specific skills can make the most impact in providing relevant health services is a necessary first step, in tandem with targeted recruitment strategies. Berman [89] and Guidotti [90] note that holistic health sector reform is necessitated globally, but particularly in low- and middle-income countries, which suggests sustained, focused, and fundamental changes in the health sector. Consideration should be given to the implementation of novel approaches, such as using technology to augment nursing skills with those of doctors or other health specialists—whether that is through telemedicine with doctors or software applications. In this way, even with a shortage of health skills in a given setting, one can turn nurse-led clinics into effective and specialist health centres.

Ultimately, the health effects associated with climate change are unlikely to be triggered by this alone, but are a consequence of localised circumstances—such as an absence of health-related services. A lack of sufficiently focused healthcare interventions within vulnerable communities further compromises individual and collective health matters when additional environmental stresses are imposed. Policy makers in health will need take into consideration avenues for both mitigation and adaptation by means of control measures, incorporating statutory, technological, educational, advisory, social, and behavioural strategies [64,87]. Moreover, a significant aspect in adapting services to climate change is to recognise climate-vulnerable communities. Evidence-based policy implementation can respond to how climate change differentially affects members of a populations, such as migrants, the elderly, youth, HIV infected individuals, and other groups [91,92]. The comparative lack of implementation science implies that policy makers also have to be proactive and pre-emptive to improve processes and systems that render healthcare amenities and services more effective in the face of climate change. Research funding could prioritise locally responsive healthcare services and health and climate impact research.

Tackling the problem of climate change and its associations with human health and healthcare services in multiple, diverse localities may be necessary, but not sufficient, unless global concerns are addressed—this can be accomplished if the process and the relationships involved are understood at both a macro and micro level. Thus, unsustainable healthcare development is not only a question of unsustainable healthcare practices in the Global South, for example, but relates to processes, practices, and relationships among states, industries, classes, communities, and individuals. Not all practices are universal, however, and some may have only local significance, such as limited healthcare services [93]. Individual-community-ecological relationships, and relationships of the community with the ‘world out there’, may be grasped in terms of global problems, and any exclusively local problem (if there is such a thing) should be approached holistically.

Author Contributions: Conceptualisation, M.d.S.; Methodology, M.d.S. and A.B.; Project administration, M.d.S. and S.K.; Funding acquisition, M.d.S.; Validation, P.K.; Formal Analysis, M.d.S.; Investigation, M.d.S.; Writing—original draft preparation, M.d.S.; Writing—review and editing, D.H., P.K., A.B., and S.K.; Supervision, D.H.

Funding: This research was funded by the Community Engagement Office of the University of South Africa (CA 7300) and a research grant from the College of Human Science, University of South Africa.

Acknowledgments: Thanks to former employees of Africa Health Placements, Caroline Simpson and Brenda Mashave, for technical support in the implementation of the study. Our appreciation also to Rhian Twine, Wits Agincourt, who assisted in arranging access to the healthcare facilities. We would also like to express our gratitude to the French government, in particular the French attaché for Science and Technology in South Africa, Jean-Paul Toutain, who under President Emmanuel Macron’s call to ‘Make our Planet Great Again’, has supported this initiative post fieldwork.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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