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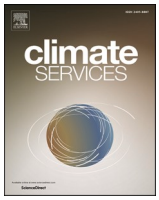

# The missing links in climate services for health and heat-health services: Examining climate-heat services in *peri*-urban districts in South Africa

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ABSTRACT

Climate services for health can facilitate health resilience and adaptation to climate change, particularly if they are well-calibrated to promote wellness and save lives. In this study, the status of climate services for health in South Africa's Agincourt sub-district, Mpumalanga province, was assessed. A qualitative case study methodology encompassing multiple methods of data collection was used. The results show that climate services for health in the Agincourt sub-district, albeit essential, are fragmented and underdeveloped. Scientifically informed heat-health services are non-existent. Notwithsatnding this gap, healthcare and allied professionals are aware of the importance of climate services for health. The main barrier to climate services delivery is the paucity of interagency coordination; for example, coordination to plan and respond to climate-health information between the South African Weather Services and the Departments of Health and Education is lacking. Inclusive climate services for health are essential for positive prevention and treatment outcomes. Future studies must provide an investment case for climate services for health, demonstrating the benefits of acting and the costs of inaction.

## Practical Implications

The practical implications of this study are twofold. First, it provides empirical evidence to practitioners dealing with climate services for health. The study shows that communities have a critical role in the development of climate services for health. Community members are the users of the services and their views must be understood for the service to be relevant. In addition, understanding the differences between scientific climate information producers and community-informed climate information is imperative. While the former produce scientific and modern climate information, the latter inform and disseminate indigenous climate information and forecasts. By definition, indigenous climate information and forecasts denote information and forecasts produced from local observations and knowledge by some community members premised on insights passed from generation to generatons within a given community. Building on the newly released National Heat-Health Guidelines in South Africa (2020) this paper argues that despite such policy a more ethically, just and fair way to integrate the messages must be found for inclusive climate services to evolve. The study probes the idea of delivering climate services through decentralised channels for consideration by practitioners. Second, the study provides information that can inform climate and health policies across scales. The study posits that policies to govern climate services for health must be formulated through a broader consultative process that encompasses transdisciplinary teams and approaches rather than a limited, top-down, linear communication approach. Policies and institutions for coordinating climate services for health must be created. It is important to acknowledge that the users of the services are not only those in the health sector but may include those from other sectors such as education as well. The results on heat-health suggest that it is imperative for countries to develop and to create policies that will guide responses to extreme heat and heat events.

*Abbreviations:* ARC, Agricultural Research Council; GCI, Global Change Institute of the University of the Witwatersrand.; GFCS, Global Framework for Climate Services; HDSS, Health and Demographic Surveillance System; NMHS, National Meteorological and Hydrological Services; SADC CSC, Southern African Development Community Climate Service Centre; SAMRC, South African Medical Research Council; SAWS, South African Weather Service; WMO, World Meteorological Organisation.

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**Data availability**

Data will be made available on request.

## Introduction

The past decade or so has witnessed a remarkable surge in interest in climate services worldwide (Tall et al., 2018; Vaughan et al., 2018; Gumucio et al., 2019). Existing global research on climate services has emphasised climate-sensitive sectors. These are sectors disproportionately affected by the vagaries of climate change and variability. They include water resources, agriculture and food security, health and energy (Patt et al., 2007). To develop adaptation and mitigation strategies for these climate-sensitive sectors, high quality, context-specific, easily accessible, affordable, usable and ethically delivered climate information is required (Adams et al., 2015; Lemos, 2015; Prokopy et al., 2017).

Africa-specific research on climate services is increasing but few Africa-focused studies have focused on climate services in specific economic sectors. Yet, sector-focused studies importantly bring to the fore sector-specific issues about climate services (Nkiaka et al., 2019). Examining climate services by sector is the most appropriate way to expose, in a nuanced manner, and initialise and identify key themes on climate services. In addition, case studies that shed light on the status of climate services in a specific sector are necessary to advance climate services research, practice and policy.

This study advances sector specific research on climate services in Africa by focusing on the health sector. Climate services for health are defined as 'the entire iterative process of joint collaboration between relevant multidisciplinary partners to identify, generate and build capacity to access, develop, deliver and use relevant and reliable climate knowledge to enhance health decisions' (WHO/WMO, 2016:15). Climate services for health are important components of a well-functioning health system.

In this study, climate services for health and heat-health services in the Agincourt sub-district of South Africa are explored. The main aim of this study was to assess the status of climate services for health and heat-health services in the area. The subsidiary objectives were to: explore the gaps in the delivery of climate services for health and heat-health services in the area; provide directions for better climate-health outcomes; provide empirical evidence for climate services for health, heat-health services and health adaptation policy and practice; and finally, highlight key areas for future research.

## Climate services in South Africa

In this section, a literature overview of climate services in South Africa is presented. In terms of policy, South Africa created the National Climate Change Response Policy in 2011 (Lukey, 2020). This policy articulates the country's roadmap towards a lower carbon economy and climate-resilient communities. South Africa's implementation of climate services is intricately linked to the Global Frameowrk for Climate Services' (GFCS) Implementation Plan approved by the World Meteorological Organisation (WMO) in 2012 (Lucio, 2013). The Plan requires all WMO member states to establish supporting frameworks for climate services at national level. To comply, South Africa developed the Road Map for the National Implementation of the GFCS in 2013 and the National Framework for Climate Services (GFCS, 2013; Government of South Africa, 2014). These documents laid the foundation for the national implementation of climate services in the country.

Davis-Reddy and Vincent (2017) note that South Africa's climate services are also linked to the Regional Climate Centre, namely the SADC Climate Service Center (SADC CSC). The SADC CSC implements several climate services programmes. South Africa participates in the Southern Africa Regional Climate Outlook Forum (Chinyoka and Steeneveld 2023, and the South-West Indian Ocean Climate Outlook Forum. These Forums bring together national, regional and international climate experts on a regular basis to produce regional climate outlooks based on data from National Meteorological and Hydrological Services (NMHS) regional and global weather and climate agencies.

South African institutions have been involved in several climate services initiatives over the past decade. Some institutions participated in the Future Climate for Africa initiative through the FRACTAL project (Pretorius et al., 2019). South African metropolitan cities of Durban, Cape Town and Johannesburg funded their participation in the FRACTAL project. The project explored decision-making processes and enhanced capacities of the three metropolitan cities to respond to climate change risks. The local Universities of Cape Town, KwaZulu-Natal and the Witwatersrand were involved in the FRACTAL project. Most recently, South Africa has been involved in the Full-Value chain Optimized Climate User-centric Services for Southern Africa (FOCUS-Africa) programme which aims to deliver tailored climate services agriculture and food security, water, energy and infrastructure in the SADC CSC (Boscolo et al., 2021).

Another initiative on climate services for water management is the HydroNet Water Control Room project implemented in the Inkomati-Usuthu Catchment Management Area (IUCMA) through a partnership between HydroLogic, eLeaf, the SAWS, Winejob, the University of Twente and IUCMA (van Rijswick et al., 2019). It used climate data to improve river and reservoir operations through data-informed decision-making. Another initiative is the collaboration between the University of KwaZulu-Natal and Umgeni Water under the Copernicus Climate Change Service (C3S) programme whereby climate data is used by Umgeni Water to manage eutrophication and water supplies to eThekwini and Msunduzi municipalities (Allison et al., 2022).

Various other South African institutions are involved in exchanging climate information and consequently advancing climate services. These institutions usually facilitate the supply-side of climate services. These include Departments of Environment, Forestry and Fisheries; Agriculture, Land Reform and Rural Development; Science and Innovation; Cooperative Governance and the Ministry of Higher Education, Science and Innovation. The SAWS, Agriculture Research Council (ARC) and Council for South African Industrial Research play pivotal in delivering climate services in South Africa.

The SAWS and the ARC established meteorological stations in several parts of the country. These stations provide vital data for weather and climate. The data underpins scientific climate forecasts for early warning systems, emergency response and decision-making for climate change response. Noteworthy, the SAWS oftentimes provides targeted climate services on commercial terms, that is, the agency sells climate information and services to customers that require them.

South African universities have also been involved in producing climate information (Mason et al., 1996). The Universities of KwaZulu-Natal, the Witwatersrand, Pretoria and Cape Town produce, analyse and exchange climate information with many stakeholders. These universities variously collaborate in modelling, downscaling and promoting the application of climate information in decision-making. An example is the Climate Information Platform of Climate System Analysis Group, which provides a holistic package of climate services to various users.

The impetus for climate services is the country's vulnerability to extreme weather events, mainly droughts and floods (Archer, 2003). Therefore, the evolving climate services have focused on climate-sensitive sectors such as water, agriculture and food security, human health, human settlements, energy, marine fisheries, disaster management and reduction and biodiversity. These can be considered climate services demand sectors.

Reviewed literature on climate and health in South Africa is diverse. It specifically highlights the direct and indirect effects of climate change on health (Myers et al., 2011; Myers 2012). For brevity, a recent systematic review on climate change adaptation in South Africa's health sector encompassing 21 studies with diverse health outcomes aptly

provides evidence on climate change and health (Chersich and Wright, 2019). The only caveat is that the review was not focused on climate services for health. Hence, some studies included in this review do not explicitly deal with this subject.

Other studies that implicitly discuss climate information for health in the country are worth mentioning. A study by Wright et al. (2019) considered climate change planning in relation to the National Health Insurance (NHI). This study importantly provides evidence on how climate change may affect health delivery through the NHI, a scheme that focuses on inclusivity in healthcare delivery. A few studies analysed the role of environmental health workers and health practitioners in climate-health interventions as well as climate change and occupational health (Kjellstrom et al., 2014; Wright et al., 2014; Shezi et al., 2019).

The National Climate Change and Health Adaptation Plan 2014–2019 clearly outlines the health-environment and climate-health issues without specifically stressing climate services. Most aspects relating to interagency co-ordination highlighted in the policy were aspirational and futuristic. Our review of the first draft of the revised National Climate Change and Health Adaptation Plan 2020–2024 suggests that climate services for health have not been amplified. Despite this, South Africa is amongst the few African countries that voluntarily respond to the WHO Health and Climate Change Survey. The responses highlight the country's progress on national adaptation plans for health. In addition, some South African cities have carried out city-level climate change risk assessments.

Notwithstanding all the efforts outlined above, reviewed literature, however, did not foreground the critical mechanisms needed for co-ordinating climate services within the sectors and across the sectors. Thus, there is a paucity of literature focusing on the "governance" of climate services in South Africa. Furthermore, existing literature places less emphasis on the inclusion of marginalised population groups in the delivery of climate services and enabling the marginal and communities to make inputs to various planning agendas (Lugen, 2016; Samuel and Jacob, 2021).

## Methodology

A qualitative case study methodology was used for this study. This methodology 'provides tools for researchers to study complex phenomena within their context' (Baxter and Jack, 2008: 544). It enabled the use of a variety of data sources and the exploration of complex interactions and relationships between individuals, communities and organisations involved in delivering climate services for health. It also facilitated an understanding of the meaning, experience and interpretations of the delivery of climate services for health from the viewpoint of the community. Finally, it promoted a broader transdisciplinary perspective by including professionals and non-professionals in the research. Transdisciplinary approaches are broadly defined in this study to encompass knowledge production, transmission, brokering and translation by formal and infomal institutions as well as professionals and non-professionals, especially vulnerable members of communities. Research participants were able to elaborate the subjective meaning, actions and social contexts relating to climate services for health as they perceived and understood them.

The qualitative case study methodology, involving various participatory actions, was chosen because it enabled the investigation of how and why questions without manipulating the behaviour of study participants. The approach also enabled detailed coverage of relevant contextual conditions associated with climate services for health in the Agincourt sub-district. And finally, it helped to reveal the often blurred and unclear boundaries between phenomena and context (Yin, 1993).

The Agincourt sub-district was purposefully selected as a sole case study area. The sub-district falls under Bushbuckridge Municipality in Mpumalanga Province of South Africa. The case study covered areas under the Health and Demographic Surveillance System (HDSS) of South African Medical Research Council (SAMRC)/University of the Witwatersrand Rural Public Health and Health Transitions Research Unit-Agincourt, as shown in Fig. 1.1. The study area and population have been extensively described in existing research (Kahn et al., 2003; 2007; Kahn et al., 2012; Tollman et al., 2008; Byass et al., 2010a; Collinson et al., 2014; Kabudula et al., 2017).

The Agincourt sub-district case study importantly provides empirical evidence on climate services for health in a *peri*-urban area in South Africa. Additional reasons that influenced the choice of the case study site was the support from the SAMRC/Wits Rural Public Health and Health Transitions Research Unit-Agincourt, that enabled access to key informants, communities and research costs. The study also benefited from leveraging the extensive track history of the HDSS and SAMRC/Wits Rural Public Health and Health Transitions Research Unit-Agincourt.

**Source:** https://www.agincourt.co.za/?page_id = 1896.

Multiple research methods were used to collect data and information. Existing literature, including peer-reviewed articles published in journals, reports and policy documents were reviewed. The reviewed literature provided important baseline information on climate information for health in the Agincourt sub-district. The literature reviewed has been reported in exiting literature which precludes a repeat of the same in this study (Manyuchi et al., 2022).

Data were also collected through an interview guide administered during interviews with key informants and community members. The interviews were conducted between September and October 2019 and in March 2020. The key informants interviewed were persons knowledgeable about the geographic area as well as recipients of subject of climate services. A purposive, snow-balling technique was used, whereby key informants provided names of other key informants and community members who would potentially voluntarily respond to the research questions. Recommended persons were followed-up and interviewed.

The study fully adhered to ethical standards for scientific research. Ethical approval for this study was provided by the Human Research Ethics Committee (Non-Medical) of the University of the Witwatersrand, Johannesburg, South Africa (protocol R14/49). The (SAMRC)/Wits Rural Public Health and Health Transitions Research Unit-Agincourt's HDSS and other research work in the communities also has existing ethical approvals with which this study complied. All study participants gave written informed consent for interviewing and recording. Interviews lasted between 45 and 60 min. Structured observations were conducted at specific venues and sites to verify information from reviewed literature and interviews. Structured observation sessions lasted about two hours.

In terms of data analysis, secondary literature was reviewed against themes that were aligned to the interview guide and research questions. Thereafter, theme-based summaries from reviewed literature were written. Data from interviews were also analysed electronically using the Atlas.Ti software package. The data were transcribed verbatim and reviewed several times. The data were then coded, and themes were generated from the codes. Theme-based summaries were then written and reviewed. Structured observation reports were also analysed electronically. Structured observation data were coded, and themes were generated. Theme-based summaries from the structured observations were written and reviewed.

The study was financially and technically supported by the Global Change Insitute (GCI) of the University of the Witwatersrand. All study participants provided written informed consent prior to participating in an interview. To ensure confidentiality, identifiers such as names of workplaces, health facilities and personal identifiers have been removed from the data presented in this study.

## Results

The key findings on climate services in general and climate services for health in the Agincourt sub-district are presented in this section.

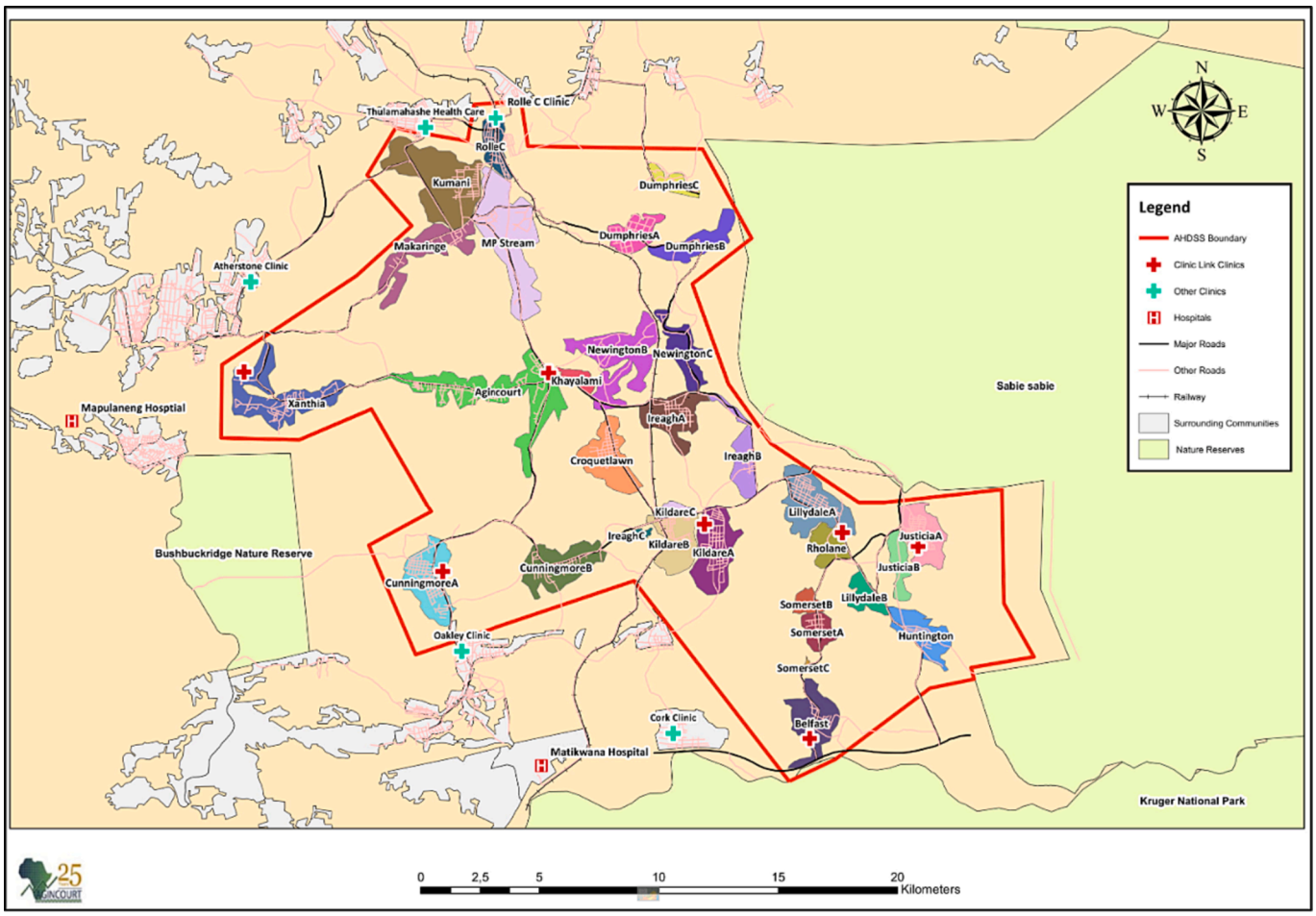


**Fig. 1.1.** SAMRC/Wits Agincourt Unit HDSS Study Area-Research Villages 2020.

These findings mainly derive from literature review and interview data, verified through structured observations. Literature on the climate background of Agincourt sub-district and social economic characteristics of the study particpants was extensively reported previously (Manyuchi et al., 2022). Therefore, the literature is not repeated in this study.

*The demographics of study participants*

A total of 93 persons were interviewed for this study. The socio-economic and demographic characteristics of study participants are shown in Table 1.1.

The study participants mostly lived in the Agincourt sub-district (85%), while about 15% lived within 150 kilometers of the area. In terms of highest education level completed, 59% of the study participants had completed matric (senior school level, Grade 12), and 24% had completed tertiary level education. Most respondents (66%) lived in the area for five years or longer. About 40% of the study participants had formal employment in health institutions, airports, a meteorological station, national park, district and provincial offices, a research institution and educational institutions.

*Accessibility to, types, and coverage of weather and climate information*

Climate and climate change are increasingly being mainstreamed into public discourse. Notwithstanding this spread of terms such as climate and climate change, many citizens, when asked, are often not clear about the crucial differences between weather, climate and climate change. To probe where people were "at" (ensuring a form of sense and meaning-making), the interviews began with ensuring a shared understanding of weather, climate and climate change.

Participants were asked to distinguish between weather and climate. About 70% of the respondents confused weather and climate to mean the same thing. One community leader stated:

> 'Weather is something that changes daily and people can feel. Climate is the situation of the weather as remembered after two days or one week or a month.'

The above statement was clarified by a teacher as follows:

> *'Community members here think and talk about the weather. They assess and deal with the weather changes daily because weather affects what they can or cannot do. Weather affects their livelihoods there and then. Issues of climate arise when community members discuss changes in seasons. But people don't talk about change of season regularly. In fact, community members tend to remember bad seasons and forget the good seasons that are considered the normal seasons. Climate is something we read in books without really reflecting on it daily.'*

Notwithstanding these interpretations, key informants did show an understanding of the concept of climate information. Access to climate information was not even and noticeable differences were recorded. The access and coverage to scientific climate information, including seasonal forecasts, is, for example, limited to professionals, thereby excluding community members. Key informants from the meteorological station, national park and airport, however, noted that they have the climate data at hand. A key informant from the national park noted:

**Table 1.1**
Demographic and socioeconomic characteristics of the participants.

| Measure | Location: Agincourt sub-district (n = 79) | | | | Location: within 150 km of Agincourt (n = 14) | | | |
|---|---|---|---|---|---|---|---|---|
| | # Male | Male % | # Female | Female % | # Male | Male % | # Female | Female % |
| **Gender** | 42 | 45 | 37 | 40 | 8 | 9 | 6 | 6 |
| **Age** | | | | | | | | |
| 19–34 years | 17 | 18 | 16 | 17 | 3 | 3 | 2 | 2 |
| 35–49 years | 12 | 13 | 12 | 13 | 3 | 3 | 3 | 3 |
| 50–59 years | 10 | 11 | 8 | 9 | 2 | 2 | 1 | 1 |
| 60 years$^{+}$ | 3 | 3 | 1 | 1 | 0 | 0 | 0 | 0 |
| **Citizenship** | | | | | | | | |
| South Africa | 27 | 29 | 26 | 28 | 6 | 6 | 6 | 6 |
| Mozambique | 10 | 11 | 9 | 10 | 0 | 0 | 0 | 0 |
| Swaziland | 3 | 3 | 1 | 1 | 0 | 0 | 0 | 0 |
| Other | 2 | 2 | 1 | 1 | 2 | 2 | 0 | 0 |
| **Race** | | | | | | | | |
| Black African | 42 | 45 | 37 | 40 | 6 | 6 | 5 | 5 |
| White | 0 | 0 | 0 | | 2 | 2 | 1 | 1 |
| **Current student status** | | | | | | | | |
| Studying | 11 | 12 | 10 | 11 | 1 | 1 | 1 | 1 |
| Not studying | 31 | 33 | 27 | 29 | 7 | 8 | 5 | 5 |
| **Highest education level completed** | | | | | | | | |
| Primary school | 5 | 5 | 11 | 12 | 0 | 0 | 0 | 0 |
| Matric | 30 | 32 | 23 | 25 | 1 | 1 | 1 | 1 |
| Tertiary education | 7 | 8 | 3 | 3 | 7 | 8 | 5 | 5 |
| **Employment status** | | | | | | | | |
| Formally employment | 15 | 16 | 12 | 13 | 6 | 6 | 5 | 5 |
| Informally employed | 16 | 17 | 15 | 16 | 2 | 2 | 1 | 1 |
| Unemployed | 11 | 12 | 10 | 11 | 0 | 0 | 0 | 1 |
| **Duration of stay in the area** | | | | | | | | |
| 11 months and less | 0 | 0 | 7 | 8 | 0 | 0 | 0 | 0 |
| 1 year to 4 years | 11 | 12 | 10 | 11 | 2 | 2 | 1 | 1 |
| 5 year and above | 31 | 33 | 20 | 22 | 6 | 6 | 5 | 5 |

*'I don't think most community members require scientific weather and climate data, unlike us in the tourism and hospitality sector who must know the daily weather forecast and the climate information because our business depends on this. This does not mean that people here do not talk about the weather. We talk about it without reference to any data. Our discussions are about how we feel when we go out there and what we think about the weather and the season.'*

In terms of accessibility, all study participants stated that weather information is readily accessible to many community members compared to climate information. They also noted that there was better coverage of weather information. Community members can get weather information whenever they need it from the radio, television and their mobile phones as well as neighbours, friends or colleagues during discussions. All participants, however, noted that the weather information is not specific to the Agincourt sub-district. The weather forecast is usually also for the next 24 hours.

In terms of the sources of weather information, about 60% of respondents stated that meteorological stations managed by the SAWS are located about 80 to 100 kilometers away from the area. The ARC weather stations located in Hoedspruit and Skukuza areas close to the Agincourt sub-district are unknown to 40 % of study respondents. Over 80% of respondents stated that South African National Parks (SANParks) has some weather stations in and around the Kruger National Park.

About 90% of respondents confirmed that community members did not have access to scientific climate data and rarely reference climate data in their discussions. About 40% of respondents stated that the processes to access the climate data are cumbersome because an application must be lodged and approved by the authorising agency before the data is released. One researcher noted:

*'Getting specific climate information from the SAWS and other agencies is not easy. An application requesting for the information must be submitted to these agencies. They take time to respond. They may give you access to the data with conditions attached to use, reporting and publication. Given this, people interested in climate information go on the internet to search for it. What they get is incomplete data which is not quality assured.'*

Despite this, respondents were clear that community members do share more than just weather information and that they shared seasonal, short term and long term climate information. They exchange seasonal climate information about whether they will have a good or bad season. One community member residing in Agincourt area stated:

*'We generally want to know whether the season will bring good rains or not. Good rains mean a good harvest and more jobs. We also want to know whether it will be too cold or not during winter. In rare circumstances, we also check whether it will be hot or not and whether we will be affected by floods.'*

Formally employed participants and students get weather information from the radio, television and internet, while most community members verbally exchange the information. Community members discuss seasonal forecasts but without reference to scientific data. In fact, the elderly and traditional healers help them in seasonal forecasting by interpreting the position and shape of the moon, animals', birds' and insects' behaviour, as well as the conditions of certain fruits, plants and flowers. One traditional healer stated that:

*'Forecasting how the season will look is a specialised area. A few spirit mediums can forecast whether the rain season will be normal or there will be drought or floods. The spirits' mediums can inform people what to do in cases of drought or floods. Apart from these mediums, there are also some people who learned how to forecast the season from their parents and grandparents. For example, we know that when certain fruits are in abundance, there is a bad season. We also know that when birds circulate*

*in a certain way, it will rain. This knowledge has been passed on from generation to generation.'*

One issue raised was that inaccurate predictions by spirit mediums have resulted in less trust in traditional climate forecasting. One weather services key informant averred:

*'Although community members share traditional weather and climate forecast among themselves. Nowadays, they tend to compare this information with scientific forecasts. However, it is not clear whether they use the information, whether traditional or scientific.'*

About 50% of community members verify the traditional forecasts with scientific forecasts because while traditional forecasting provides generalised ideas of what to anticipate, scientific forecasts sometimes provide the date and times of the events. One community leader noted:

'*Traditional forecasts are quite general. They give us an idea of what to expect without providing the actual dates. This information is vital because it makes us prepare in advance. We then listen to weather forecasts to be certain of the dates when the predicted event will happen. If one uses the two, one will never be surprised when an adverse weather event happens.'*

The role of indigenous knowledge on climate and health, in particular, in relation to scientific climate information was explored in further detail. About 70% of study participants noted that a few community members are aware of the indigenous knowledge that influence the health-seeking behaviours of community members. About 60% participants stated that few elderly people, as well as some traditional healers, can identify diseases that can be associated with climate change and variability. A traditional healer in the area stated:

*'We know that most of these illnesses result from drinking unclean water, eating poor quality foods, eating infected and even poisonous fruits during periods of drought, as well as dehydration during extremely hot days. These sicknesses mainly affect children, the elderly and those with underlying medical conditions. Most traditional healers and herbalists are aware of traditional remedies for these health complications that may be associated with climate change.'*

Respondents noted that most community members go either to church leaders, some elders or traditional healers and to herbalists for consultations and treatment. One voluntary community development worker stated:

*'Most people go to herbalists who will give them some traditional herbs to deal with minor ailments arising from heat and other sicknesses of weather. The problem is that the herbalist always keep their practices a secrete. Some community members go to churches where they get oil or water as well as prayers. The interventions of churches and herbalists are helpful to those who believe in their value.'*

About 48% of respondents stated that when the traditional and religious solutions fail, community members then visit the healthcare centres. About 90% of respondents stated that community members concurrently use traditional and faith-based remedies together with medications from health facilities. One midwife stated:

*'Community members tend to try all forms of available ways to be healed or cured. While most start first at herbalists, others start at the churches. What is clear is that if the solutions from the herbalists and faith leaders do not work, the members end up going to the healthcare centres. Sometimes they are referred to the clinics by the herbalists and the faith leaders.'*

The health solutions provided by faith leaders were also explored. One faith leader noted:

*'Although our interventions are usually spiritual, at times we provide practical solutions to problems. We sometimes provide oil, water and other protection items to children of God so that they experience the healing power of God. We believe God is the ultimate healer for any condition, even weather and climate-related sickness. And we know most of our believers use these, and they find them effective.'*

All participants suggested that climate services for health should integrate scientific and indigenous knowledge. The main issue is how to collect and communicate these.

*Institutions for and community involvement in climate services*

About 98% of respondents stated that scientific climate data are produced by weather services. Key informants employed at the weather services stated that they generated the weather information and provided it to the national (SAWS, SANParks and (ARC to disseminate. These institutions have no mandate and capacity to disseminate scientific climate information to local communities. Respondents could not explain the flow of ARC and SANParks data. However, the key informants pointed out that these institutions use the data in their own operations and share weather data with the SAWS.

All participants stated that community members are usually not involved in producing climate information or indigenous seasonal forecasts. In the Agincourt area, however, a few formal and informal institutions such as SA Weather Services, the elderly, traditional healers and spirit mediums participate in producing climate information. Despite this, they acknowledged that most community members are informally involved in disseminating climate information. One key informant from a health center noted:

*'The weather stations work in silos. Station employees are the only ones who generate the climate information. Likewise, the elders do not call people to ask whether the season will be good or bad. They analyse the conditions and predict how the season will look. They tell their close associates, and the information is spread into the communities. People learn about the seasonal forecasts as they share the information.'*

Participants confirmed that leadership and co-ordination institutions for climate services in the area are unclear. About 72% of study participants suggested that the leadership should come from professionals working in local institutions. About 84% of respondents were unaware of who should produce and deliver climate information and could not recall any 'policies' that facilitate the production and delivery of climate information to the community. These participants, however, were keen to get access to climate information. They suggested that climate information should be delivered in their local language using existing channels, including radio, mobile phones, televisions, health and educational institutions. Given the eagerness for some form of climate information, attention was focused on further exploring the demand for climate services.

*Demand for and investments in climate services*

All participants stated that every person in the community requires climate information in one way or another. They also noted that there is great demand for climate services among staff working in national parks, airport, health facilities, schools, churches, farmers, miners, research institutions, as well as persons working in formal and informal settings. All participants noted that although vulnerable persons need climate information, climate information 'structures' to cater for them are non-existant. One community health worker stated:

*'Most chronically ill persons will be happy to know well in advance weather changes. This will enable them to go to health centres to get their medication rather than planning to go on a day when the weather will be bad. Similarly, we have elderly persons who attempt to get social grants on certain days and find themselves under terrible weather. This can be avoided if they get weather information prior to their trip. In the area of agriculture, predicting how the season will be can help farmers plan the dates to plant and the types of crops to grow.'*

Participants suggested that targeted climate information delivery would be more effective if it is tailored for vulnerable members of the community. One key informant working at the airport stated:

*'What we tend to get is general information and one has to think how it applies to their circumstances. My suggestion is climate information must target specific population groups. It will be good to get information that informs elders which weeks they can go to get their social grants, or which days children can write their exams without being affected by extreme weather conditions. Similarly, if clinics get information, they can plan admissions of pregnant mothers, amongst other decisions.'*

About 86% of respondents stated that communities demand seasonal climate information that indicate the actual days when the community will be affected by adverse climate events such as floods, extremely hot and extremely cold days and droughts. About 92% of key informants suggested that communities would like information on when to expect malaria, diarrhoea and other diseases to increase. Farmers want information on what types of crops to grow before the onset of the rain season and what pests and diseases to expect. Other employers require forecast information on days their employees will be unable to work for them to arrange other activities or give their staff leave days. One brickmaking entreprenuer said:

*'My work is outdoor(s), and I am self-employed. If I know in advance how the season will look, I will plan my days properly so that I go back to my rural home when it is impossible to work. Unfortunately, we do not have that information, and we continue coming to work, only to go back home without doing anything.'*

The perceptions on investments necessary for climate services and whether community members would be willing to pay for the services were also explored. All participants stated that community members were too poor to pay for climate services. They suggested that government must partner with mining firms and other private companies to pay on behalf of the poor communities. Participants recommended that private firms should also pay for the specific climate information they require.

### *Status of climate services for health*

The status of climate services for health in the area was also investigated. All key informants and respondents stated that climate information services for health are not fully developed. One key informant from a health facility stated:

*'The state of climate information for health is that of fragmentation. Individuals get their own information. There is no institutionalised process to deliver the climate information for health here. Yet, the information is important. It can help improve treatment outcomes.'*

About 78% of respondents stated that there is no interaction between healthcare workers and meteorological officers, which makes it impossible to share climate data. In addition, since weather services charge some fees for people to access data, this hinders the sharing of climate data. They suggested that the climate information must be produced at a local level.

### *The types of climate-health information required*

Having established if climate services would be of value in local decision-making, the nature and type of climate services related to health were further probed. All participants stated that communities primarily need seasonal forecasts on rainfall and drought as well as context-specific weather and climate information that shows the probability of an extremely hot day, rain, thunderstorm, floods, humidity and windy days, among other conditions. One community leader aptly stated:

*'The key climate-health information we need is on the rain season, that is, whether we will have sufficient rainfall or we will experience a drought. This information will help us [to] plan which crops to plant. It helps us decide on the right time to buy and store foodstuff in case of drought. It also shows us whether the community will be affected by malnutrition or not. It will demonstrate to us whether our water sources will be affected or not. That information will indicate whether we will have fruits and vegetables. The information will indirectly show the pests and insects that may affect us, and we fear malaria.'*

All participants noted that wind carries with it dust particles associated with respiratory infections. Dusty winds affect people with respiratory diseases such as asthma and limits visibility. Participants pointed out that mining operations in the area are a source of dust. Therefore, information on wind speed and direction is important as part of the climate-health information package. Key informants specifically emphasised the importance of information on humidity. They noted that humid conditions make people feel hot. Information on hot days importantly informs them on what activities to engage in and whether children can go to school or not. In addition, heat information is essential because it enables communities to create interventions to prevent dehydration and diarrhoea, especially among children.

About 38% of participants stated that climate-health information on extreme weather events is useful, especially forecasts on floods, thunderstorms and hailstorms. These forecasts are crucial for people caring for people living with disabilities, vulnerable community members, people who work outdoors as well as those who travel long distances to and from work on foot.

### *Communicating climate services for health*

Efforts were extended to find out what would be some of the most accessible channels for communicating the climate services. All participants stated that posters and pamphlets written in local languages and posted at health facilities, community centres, churches, schools, shopping areas and other public places are an acceptable means to communicate climate information for health. Selected community leaders can also distribute posters and pamphlets. Participants stated different views on the role of agriculture extension services in disseminating climate-health information. While 52% of study participants thought agricultural extension workers would be effective, others thought this was not their area of focus and a different mechanism is required to engage with farmers.

About 96% of study participants noted that disseminating climate-health information through WhatsApp, radio, short-text messages on mobile phones, and verbal announcements will enable the information to reach many people. The importance of television was debatable because it is unable to distribute Agincourt sub-district-specific information. About 72% of study participants concluded that the television is an inappropriate channel to communicate climate-health information for the area. Respondents suggested using social media platforms such as Facebook and Instagram.

All key informants noted the importance of verbally communicating the information to community leaders. The community leaders and influencers share the information verbally during their interactions with individual community members, and they will announce the information during community events.

### *Investing in climate services for health*

Finally an assessment of perceptions on the investment necessary for climate services was also done. About 72% of key informants stated that money should be invested in creating physical and virtual platforms for sharing climate information. About 66% of respondents suggested more investments in building new weather stations. They stated that each health facility and school must have a weather station, and investments

must be directed towards training targeted personnel in schools, health facilities as well as community representatives to manage and analyse data from the weather station to provide localised information. They huighlighted that investments in capacity building must target professionals working with the data so that they can interact with stakeholders and produce consensus-based climate services.

All respondents stated that the government must pay for these services because they are for the greater good of everyone in the community. In fact, community members would be unwilling to pay for health climate services. Respondents argued that government must pay because climate services for health are a preventative rather than curative approach to healthcare delivery, and they create savings for the government by reducing costs associated with treating sick patients.

*The state and content of heat-health services in the Agincourt sub-district*

Since existing literature and meteorological data show that the Agincourt sub-district is already experiencing heat and heatwaves and communities will be affected by heat and heatwaves in future (Kruger et al., 2002; Kruger and Sekele, 2013; Kruger and Shongwe, 2004; Byass et al., 2017; Macfadyen et al., 2018; dos Santos et al., 2019; South African Weather Service, 2019; Mbokodo et al., 2020; van der Walt and Fitchett, 2020) the evolving heat-health services in the area were explored. Respondents suggested that since the Agincourt area was already experiencing extreme heat, heat-health services were supposed to be prioritised. Overall, all participants stated that scientifically informed heat-health services were, however, non-existent in the Agincourt sub-district. However, heat-health information informed by indigenous knowledge may be in existence, albeit the extent of their coverage is unknown.

The types of heat-health information communities that residents in the Agincourt would require is not too onerous and includes information such as the days when it will be too hot and humid, days with less wind and days when extreme heat will be followed by rain and cold. Conveying issues of uncertainty of the science and the probabilistic nature of the information is a concern and would require more effort and continuting trust building and awareness with communities. All participants noted that information on hot days should be forecasted and reported at least two weeks in advance to give community members time to prepare a response. They also suggested that a seasonal forecast of hot days would be very important if it were possible to have this information. However, further probing showed that this suggestion was a request for information when the rain season would be interrupted by a brief period of drought or extreme dry days.

About 82% of study participants stated that heat forecasting is important because it would help them prepare in advance to reduce the health effects of heat. These participants noted that communities would store large quantities of clean water, food and buy or collect medications in advance. About 24% of study participants stated that heat-health forecast information would enable them to disseminate the information in the community. They noted that providing heat information in advance allows every member of the community to be ready for the heat or extreme heat events.

All respondents stated that community members that would benefit most from heat-health information include the elderly, children, people living with disability and people on chronic medications. They stated that heat-health information is complex to explain and must be disseminated to a limited number of key persons, including community leaders, traditional healers/herbalists, teachers and healthcare workers. These people must cascade the information to other community members. However, some key informants disputed this. They argued that some community leaders and influencers might politicise or fail to articulate the information and even misinform others. They suggested that heat-health information be disseminated widely through diverse channels and every community member be involved in the production and delivery of the services. Thus, all respondents emphasised that heat-health services are essential for everyone in the area.

*Community and medical staff awareness of heat-health impacts*

To complete the research an investigation of community and medical staff awareness of heat-health effects was also undertaken. Study participants and medical staff showed an excellent understanding of the health effects of extreme heat. They reported that many community members would be able to articulate the direct and indirect impacts of extreme heat anomalies and relate these to general health. Participants ascribed their understanding of the heat-health effects to the fact that they live in a generally hot area. Key informants stated that although heat-health campaigns are lacking in the Agincourt area, they are necessary and should be integrated into existing campaigns that are conducted by healthcare providers in the area.

Key informants noted that the area required early warning systems for extreme events, including extreme heat. One key informant from a meteorological station stated:

> *'We have weather and climate data. We do not have capacity to translate this to be useful for health interventions in this area. It will be good to do so, but right now, it is practically impossible. Which agency must lead this? The area needs early warning systems for a variety of natural disasters.'*

All participants stated that a heat-health early warning system was supposed to be informed by community knowledge of the area as well as scientific information. The participants highlighted that two-way communication and participation of the community in the production of a heat-health response system is necessary.

The investments necessary, as well as the co-ordination of a heat-health response system, were however noted as key concerns. All participants stated that investments in heat-health services should be made by government because these services are aimed at saving lives. However, about 52% of study participants pointed out that some firms, especially mining firms, farms and national parks must invest in heat-health services because their employees are vulnerable to heat exposure. By investing in these services, the firms would be directly and indirectly protecting their employees and their families. The suggested investment areas included training, capacity building and community relations.

In terms of co-ordination of the heat-health system, participants held different views. While 92% of participants thought that the leads should be staff at meteorological stations and the SAWS, about 8% of participants suggested health department staff. However, all key informants noted that the system must involve co-chairing or co-leadership by employees from the weather stations and the health department.

## Discussion and implications for climate services

In this article, a detailed assessment of the existence of and need for climate services was probed in the Agincourt sub-district of South Africa, an area already experiencing change and noted to undergo significant climate shifts in the future. This study is one of the most comprehensive efforts to assess the status and content of climate services for health and heat-health services in the area. A number of key insights emerged, including not only types of information needed but also the institutional and 'processes' required to ensure effective use and uptake of weather and climate information.

The study results show that scientifically informed climate services are not well-developed in the Agincourt sub-district. In addition, heat-health services are non-existent in the area. The limited scientific climate information accessible to the communities is disseminated from the national level. This information, while good in coverage, is too general to inform local-level decision-making processes.

Therefore, the current scientific climate information the populations can access lacks 'people-centredness'. People-centredness can be viewed

as analogous to patient-centred care (Ekman et al., 2021; van Diepen and Wolf, 2021). Patient-centred care demands considering the patient's information needs, shared decision-making and implementing appropriate responses informed by the process and substance of dialogue (Stewart, 2001). People-centredness underscores the centrality of users of climate services as the reason for existence and delivery of the services. Hence, climate services for health must be people-centred and co-delivered in a manner that recognises the importance of the involvement of users.

The delivery of services that is not people-centred may not be limited to the Agincourt sub-district. It is posited that this may be a general challenge found across many other areas in the country and indeed in other countries where scientific climate information is disseminated from a centralised system. It can be assumed that it is difficult to establish a balance between centralised delivery of climate services and people-centredness. Hence, delivering climate services for health using decentralised models may be necessary to explore in future studies.

The study findings also point to the very valuable role that indigenous knowledge can play in heat and health services. While the coverage of the services could not be established, the mechanisms by which they function, including community involvement in information dissemination, were clearly articulated. The indigenous knowledge-based climate services for health are produced *within* the communities and delivered *by* community members, two critically important dimensions of transdisciplinary research. Hence, they are community-specific and people-centred to a certain extent. However, they are exclusive to populations that do not interact with the producers of these services or their associates. To enhance people-centredness in the delivery of climate services for health, efforts to integrate scientific and traditional systems of services delivery must be made. Principles of co-production and co-delivery must undergird the integration process.

The study results also critically highlight the multilevel institutions that explicitly and implicitly influence climate services, including climate services for health in South Africa. Our findings importantly show that the governance of climate services, health climate services and heat-health services is fragmented and lack clear leadership. Current production and delivery of climate services, including climate services for health, happens in silos. Our findings suggest that the SAWS generates and distributes climate information with little to no involvement of other stakeholders, including those from the health sector. Co-ordination across the various government agencies is also very weak. Moreover, efforts to co-ordinate scientific and traditional services systems are non-existent. The involvement of communities within the multilevel structures of governance is not robust and meaningful. Without community involvement, it is difficult for climate services to impact local-level decision-making.

Climate services for health and heat-health services require transdisciplinary approaches in their implementation. Intrinsically, climatologists/meteorologists and climate communication specialists must collaborate with healthcare and allied workers to deliver relevant and impactful climate information for health, particularly heat-health information. The study results demonstrate that transdisciplinarity must also include other 'knoweldge holders' such as indigenous healthcare providers, including traditional healers, herbalists and faith-based leaders. These undervalued stakeholders all contribute inputs to climate and weather knowledge and healthcare advice that influence some members of the community. These actors, their message and practices are in many instances robust and have been used over the years.

One critical omission in Agincourt area renowned for its long-term health data tracking is that climate services for health and heat-health services are not institutionalised and not inclusive of various sources of information. Applying an inclusive system of climate services requires broadening the transdisciplinary lenses to include other non-professional community leaders and community members.

The use of locally available technologies is also imperative for inclusive systems of climate services, including climate services for health and heat-health services. The results show that climate services are accessed using locally available technologies and informal information dissemination channels that have existed over time. This finding is very important because it calls into question the efficacy of current climate information products. Hence, a review of current climate information products is encouraged. This finding also shows that countries should not adopt a 'one-size-fits-all' approach to the delivery of climate services for health and heat-health services. Some of the current communication products must be upheld. For example, the finding that posters and pamphlets targeted at specific public venues must be used to deliver climate services for health and heat-health information demonstrates the belief in their efficacy as a public health communication tool. The reported centrality of verbal exchange of climate information in rural settings calls for innovative ways to co-deliver climate services for health and heat-health information.

A key point that can be drawn from the results is that interactive learning is important in facilitating the co-delivery of climate services. Interactive learning provides insights on the co-delivery of climate services to vulnerable populations such as children, the elderly, people living with disability and people on chronic medications. In the Agincourt sub-district, traditional forecasting systems demonstrated inherent elements of interactive learning, while there is little interactive learning in scientific climate information.

The exploration of the perceptions of the necessary investments for climate services, including climate services for health and heat-health services, provided invaluable and new information not exposed in existing literature. The key findings on investment show that resources for climate services must be provided by government, while the private sector can complement government efforts, and firms must pay for climate products specific to their needs related to responding to the impacts of climate on their employees. Despite the need for several forms of support, the results suggest the existence of a very strong view that governments must invest in climate services for health and heat-health because the populations are poor to accept the user-pays principle, and climate services for health and heat-health services are life-saving investments. These findings are very important as they provide unequivocal empirical evidence to African governments to invest in climate services for health and heat-health services.

The study results also demonstrated that investments for climate services for health and heat-health services must be directed towards training, capacity building, stakeholder relations and infrastructure, especially weather stations. Existing literature highlights the importance of investing in infrastructure and capacity building without alluding much to investments in training and stakeholder relations (Dinku, 2011; Dinku et al., 2011; 2014). Therefore, the study findings are very important for the African continent, where the density of weather stations is unacceptably low. The suggested investments in training are important in the African context, where many countries are affected by skilled labour shortages. While investments in stakeholder relations were alluded to, this may be considered as part of the capacity building exercise.

One infrastructural need is the importance of a developing effective heat-health early warning systems. Existing literature clearly shows that heat is going to affect many African communities, including communities in and around the Agincourt sub-district (Byass et al., 2010b; Byass et al., 2017; dos Santos et al., 2019). Therefore, it is important for the South African and other African governments to create heat policies. While this study did not establish the costs of inaction, several studies carried out in other settings show excess deaths and increased morbidities from extreme heat events (Smith et al., 2016; Campbell et al., 2018).

One group of actors that can assist government is the healthcare workers. The results showing increased awareness of the effects of extreme events on health among medical staff confirm what is reported in existing literature elsewhere (Watts et al., 2020). However, the

practical application of such knowledge to save lives and assist those affected is lacking. Heat-health campaigns are recommended. A detailed analysis of existing interventions that have enabled the communities to be resilient to past temperature anomalies encompassing traditional healers and faith leaders is encouraged.

Remaining questions include: What investments must be made towards integrating the scientific and indigenous systems climate services for health, who does this and who maintains, sustains and implements such services? The role of other knowledge hodlers is also key: How can we integrate indigenous producers and disseminators of climate services, including climate services for health and how can this rich knowledge be sustained?

The study can be judged to be scientifically robust based on the degree to which findings are reproducible, replicable and generalizable. The research design, sampling method and sample size, as well as the use of appropriate methods for data collection and analysis were thoroughly explained. In addition, most participants (83%) completed education levels that would allow them to give insightful responses to the subject under research. Gender parity was achieved as males and females equitably participated in the study. Structured observations and the involvement of people living outside of the Agincourt sub-district helped give an outsider perspective to the study necessary in corroborating or refuting evidence and minimising bias. Triangulating multiple data sources increased the reliability and validity of the findings.

There are, however, some study limitations. The data collected in this study focused on South Africa, specifically the Agincourt sub-district. Therefore, the generalisability of the study findings is limited. As such, any generalisations that were made from this study were qualified. While attempts were made at reaching data saturation on each theme, there is no gold standard to refer to ascertain with certainty that data saturation was reached on all themes. The study number of participants may be considered low. However, it can be argued that the 93 participants included in the study was an acceptable number. While some participants interviewed were referred by key informants, which creates bias, some participants were selected outside of the referral chains to minimise bias associated with use of snowballing technique for recruitment.

## Conclusion

In this article, a detailed case study of the status of climate services, emphasising climate services for health and heat-health services in South Africa's Agincourt sub-district, has been presented. A qualitative case study methodology encompassing multiple data collection methods was used. The study presented several African based findings on climate services, climate services for health and heat-health services in the Agincourt sub-district.

The findings show that the provision of climate services is still fragmented, notwithstanding existing policy frameworks and supporting institutions to deliver these. Although research on climate services for health has been evolving for almost a decade now, the actualisation and delivery of the services are limited. Hence, climate services for health are underdeveloped.

While climate data shows that the population has been and will continue to be affected by heat and heat events, the results show that heat-health services are non-existent. This is of great concern. Planning for heat and heatwaves is essential to minimise the health effects of these climate-related conditions. Although this study provides detailed information for adaptation research, policy and practice, we recommend further research that examines the cost of acting or not taking any action against the changing climatic conditions and extreme events in the sub-district. Further research on heat and health, as well as responses to heat stress and heatwaves, is encouraged.

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*Data Availability Statement*

Qualitative datasets that are restricted and not publicly available. Due to confidentiality agreements, supporting data can only be made available to bona fide researchers subject to a non-disclosure agreement. Details of the data and how to request access are available from A.E. Manyuchi at Global Change Institute of The University of the Witwatersrand.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

Data will be made available on request.

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## References

Adams, P. et al. (2015) Toward an ethical framework for climate services. *WMO Bulletin* 4 64(2), pp. 51–54. 10.13140/RG.2.1.1029.0645.

Allison, L.C., Palmer, M.D., Haigh, I.D., 2022. Projections of 21st century sea level rise for the coast of South Africa. Environmental Research Communications 4 (2), 025001.

Archer, E.R.M., 2003. Identifying underserved end-user groups in the provision of climate information. Bull. Am. Meteorol. Soc. 84 (11) https://doi.org/10.1175/BAMS-84-11-1525.

Baxter, P., Jack, S., 2008. Qualitative Case Study Methodology: Study Design and Implementation for Novice Researchers. Qual. Rep. 13 (4), 544–559. https://doi.org/10.2174/1874434600802010058.

Boscolo, R., Bastani, H., Beraki, A., Fournier, N., Marcos-Matamoros, R., Troccoli, A., Dkhissi, Y., Kamga, A., Lumsden, T., Bojovic, D., Dell'Acqua, M., Omrani, H., and Mateyisi, M.: *Demonstrating the full-value chain of climate services in Southern Africa: the FOCUS-Africa project*, EMS Annual Meeting 2021, online, 6–10 Sep 2021, EMS2021-460, https://doi.org/10.5194/ems2021-460, 2021.

Byass, P., Kahn, K., et al. (2010a) Moving from data on deaths to public health policy in Agincourt, South Africa: Approaches to analysing and understanding verbal autopsy findings. *PLoS Medicine* 7(8). 10.1371/journal.pmed.1000325.

Byass, P., Twine, W., Collinson, M., Tollman, S., Kjellstrom, T., 2010b. Assessing a population's exposure to heat and humidity: an empirical approach. Glob. Health Action 3 (1), 5421.

Byass, P., Collinson, M.A., Kabudula, C., Gómez-Olivé, F.X., Wagner, R.G., Ngobeni, S., Silaule, B., Mee, P., Coetzee, M., Twine, W., Tollman, S.M., Kahn, K., 2017. The long road to elimination: malaria mortality in a South African population cohort over 21 years. Global Health, Epidemiol. Genom. 2, e11. https://doi.org/10.1017/gheg.2017.7.

Campbell, S., Remenyi, T.A., White, C.J., Johnston, F.H., 2018. Heatwave and Health Impact Research: A Global Review. Health Place 53 (February), 210–228. https://doi.org/10.1016/j.healthplace.2018.08.017.

Chersich, M.F., Wright, C.Y., 2019. Climate change adaptation in South Africa: a case study on the role of the health sector. Glob. Health 15 (1). https://doi.org/10.1186/s12992-019-0466-x.

Chinyoka, S., Steeneveld, G.J., 2023. Evaluation of downscaling seasonal climate forecasts for crop yield forecasting in Zimbabwe. Clim. Serv. 30, 100380.

Collinson, M.A., White, M.J., Bocquier, P., McGarvey, S.T., Afolabi, S.A., Clark, S.J., Kahn, K., Tollman, S.M., 2014. Migration and the epidemiological transition: Insights from the Agincourt sub-district of northeast South Africa. Glob. Health Action 7 (1), 23514.

Davis-Reddy, C.L., Vincent, K., 2017. Climate Risk and Vulnerability: A Handbook for Southern Africa, 2nd Ed. CSIR, Pretoria, South Africa.

Dinku, T., 2011. ENACTS Ethiopia: Partnerships for Improving Climate Data Availability, Accessibility, and Utility. Climate Services Partnership 1–7.

Dinku, T., et al., 2011. Improving availability, access 1 and use of climate information. Available at: WMO Bull. 60 (2), 80–86 http://public.wmo.int/en/bulletin/improvingavailability-access-and-use-climate-information.

Dinku, T., et al., 2014. Bridging critical gaps in climate services and applications in Africa. Earth Perspectives 1 (1), 15. https://doi.org/10.1186/2194-6434-1-15.
dos Santos, M., Howard, D., Kruger, P., Banos, A., Kornik, S., 2019. Climate change and healthcare sustainability in the Agincourt sub-district, Kruger to Canyons Biosphere Region, South Africa. Sustainability 11 (2), 496.
Ekman, I. Ebrahimi, Z and Contreras P.O. (2021) Person-centred care: looking back, looking forward. *European Journal of Cardiovascular Nursing* pp. 4–6. 10.1093/eurjcn/zvaa025.
GFCS SA (2013) *Road Map for the National Implementation of the Global Framework for Climate Services*. Developed on the basis of the stakeholder workshop held 19 – 22 August 2013, Pretoria, South Africa, Pretoria.
Government of South Africa, 2014. National Framework for Climate Services (NFCS-SA). Department of Environmental Affairs, Pretoria.
Gumucio, T., et al., 2019. Gender-responsive rural climate services: a review of the literature. Clim. Dev. 1–14. https://doi.org/10.1080/17565529.2019.1613216.
Kabudula, C.W., et al., 2017. Progression of the epidemiological transition in a rural South African setting: findings from 1 population surveillance in Agincourt, 1993–2013. BMC Public Health 17 (1), 1–15. https://doi.org/10.1186/s12889-017-4312-x.
Kahn, K., et al., 2007. Research into health, population and social transitions in rural South Africa: Data and methods of the Agincourt health and demographic surveillance system. Scandinav. J. Public Health 35 (SUPPL. 69), 8–20. https://doi.org/10.1080/14034950701505031.
Kahn, K., Collinson, M.A., Gomez-Olive, F.X., Mokoena, O., Twine, R., Mee, P., Afolabi, S. A., Clark, B.D., Kabudula, C.W., Khosa, A., Khoza, S., Shabangu, M.G., Silaule, B., Tibane, J.B., Wagner, R.G., Garenne, M.L., Clark, S.J., Tollman, S.M., 2012. Profile: Agincourt health and socio-demographic surveillance system. Int. J. Epidemiol. 41 (4), 988–1001.
Kahn, K. et al. (2003) Health consequences of migration: Evidence from South Africa's rural northeast (Agincourt). Paper prepared for Conference on African Migration in Comparative Perspective, Johannesburg, South Africa, 4-7, June, 2003, pp. 0–26.
Kjellstrom, T., Lemke, B., Hyatt, O., Otto, M., 2014. (2014) Climate change and occupational health: A South African perspective. S. Afr. Med. J. 104 (8), 586.
Kruger, A.C., Sekele, S.S., 2013. Trends in extreme temperature indices in South Africa: 1962–2009. Int. J. Climatol. 33 (3), 661–676. https://doi.org/10.1002/joc.3455.
Kruger, A.C., Makamo, L.B., Shongwe, S., 2002. An analysis of Skukuza climate data. Koedoe 45 (1), 1–7. https://doi.org/10.4102/koedoe.v45i1.16.
Kruger, A.C., Shongwe, S., 2004. Temperature trends in South Africa: 1960–2003. Int. J. Climatol. 24 (15), 1929–1945. https://doi.org/10.1002/joc.1096.
Lemos, M.C., 2015. Usable climate knowledge for adaptive and co-managed water governance. Curr. Opin. Environ. Sustain. 12, 48–52. https://doi.org/10.1016/j.cosust.2014.09.005.
Lucio, F., 2013. Global Framework for Climate Services (GFCS): implementation approach. EGU General Assembly Conference Abstracts.
Lugen, M. (2016) *The role of climate services for adaptation to climate change in developing countries, with a case study from South Africa*. KLIMOS Working Paper n°10, KLIMOS-ACROPOLIS, Brussels, Belgium.
Lukey, P. (2020). *The South African National Climate Change Response Policy – an evidence-based policy-making case study*. Department of Environment, Forestry and Fisheries, Pretoria.
MacFadyen, S., Zambatis, N., Van Teeffelen, A.J.A., Hui, C., 2018. Long-term rainfall regression surfaces for the Kruger National Park, South Africa: A spatio-temporal review of patterns from 1981 to 2015. Int. J. Climatol. 38 (5), 2506–2519.
Manyuchi, A.E., Vogel, C., Wright, C.Y., Erasmus, B., 2022. The self-reported human health effects associated with heat exposure in Agincourt sub-district of South Africa. Human Soc. Sci. Commun. 9 (1) https://doi.org/10.1057/s41599-022-01063-1.
Mason, S.J., Joubert, A.M., Cosijn, C., et al., 1996. Review of seasonal forecasting techniques and their applicability to Southern Africa. Water SA 22 (3), 203–209.
Mbokodo, I., et al., 2020. Heatwaves in the 1 future warmer climate of South Africa. Atmos. 11 (7), 1–18. https://doi.org/10.3390/atmos11070712.
Myers, J., et al., 2011. A public health approach to the impact of climate change on health in southern Africa - Identifying priority modifiable risks. S. Afr. Med. J. 101 (11), 817–820. https://doi.org/10.7196/SAMJ.5267.
Myers, J., 2012. The South African burden of disease and climate change. Continuing Medical Education 30 (3), 72–75.
National Department of Health, 2020. National Heat Health Action Guidelines. Department of Health, Pretoria.
Nkiaka, E., Taylor, A., Dougill, A.J., Antwi-Agyei, P., Fournier, N., Bosire, E.N., Konte, O., Lawal, K.A., Mutai, B., Mwangi, E., Ticehurst, H., Toure, A., Warnaars, T., 2019. Identifying user needs for weather and climate services to enhance resilience to climate shocks in sub-Saharan Africa. Environ. Res. Lett. 14 (12), 123003.
Patt, A.G., Ogallo, L., Hellmuth, M., 2007. Sustainability. Learning from 10 years of climate outlook forums in Africa. Science (New York, N.Y.) 318 (5847), 49–50. https://doi.org/10.1126/science.1147909.
Pretorius, L. *et al.* (2019) *An Embedded Researcher approach to integrate climate information into decision making in southern African cities: lessons from FRACTAL*. FRACTAL Working Paper #8, Future Climate for Africa.
Prokopy, L.S., Carlton, J.S., Haigh, T., Lemos, M.C., Mase, A.S., Widhalm, M., 2017. Useful to Usable: Developing usable climate science for agriculture. *Climate*. Risk Manage. 15, 1–7.
Samuel, D., Jacob, D., 2021. From participatory to inclusive climate services for enhancing societal uptake. Clim. Serv. 24 (October) https://doi.org/10.1016/j.cliser.2021.100266.
Shezi, B., Mathee, A., Siziba, W., Street, R.A., Naicker, N., Kunene, Z., Wright, C.Y., 2019. Environmental health practitioners potentially play a key role in helping communities adapt to climate change. BMC Public Health 19 (1). https://doi.org/10.1186/s12889-018-6378-5.
Smith, S., Elliot, A.J., Hajat, S., Bone, A., Smith, G.E., Kovats, S., 2016. Estimating the Burden of Heat Illness in England during the 2013 Summer Heatwave Using Syndromic Surveillance. J. Epidemiol. Community Health 70 (5), 459–465. https://doi.org/10.1136/jech-2015-206079.
South African Weather Service (2019) Annual Climate Summary for South Africa 2018. pp. 1–29. Available at: https://www.weathersa.co.za/Documents/Corporate/Annual Climate Summary 2018 FINAL.pdf.
Stewart, M., 2001. Towards a global definition of patient centred care: The patient should be the judge of patient centred care. Br. Med. J. 322 (7284), 444–445. https://doi.org/10.1136/bmj.322.7284.444.
Tall, A., Coulibaly, J.Y., Diop, M., July 2017. (2018) Do climate services make a difference? A review of evaluation methodologies and practices to assess the value of climate information services for farmers: Implications for Africa. Clim. Serv. 11, 1–12. https://doi.org/10.1016/j.cliser.2018.06.001.
Tollman, S.M., et al., 2008. Implications of mortality transition for primary health care in rural South Africa: a population-based surveillance study. Lancet 372 (9642), 893–901. https://doi.org/10.1016/S0140-6736(08)61399-9.
van der Walt, A. J. and Fitchett, J. M. (2020) Statistical classification of South African seasonal divisions on the basis of daily temperature data. *South African J. Sci.*, 116 (9–10), pp. 1–15. 10.17159/sajs.2020/7614.
van Diepen, C. and Wolf, A. (2021) Care is not care if it isn't person-centred. A content analysis of how Person-Centred Care is expressed on Twitter. *Health Expectations* 33 (July 2020), pp. 1–8. 10.1111/hex.13199.
van Rijswick, H.F.M.W., Buijze, A.W.G.J., Jackson, B., Schmidt, B., Schous, J., Wörner, R. and Makkinje, A.C., 2019. *Mind the gaps in sustainable water governance: Lessons from strategic adaptive management in the InComati river basin*.
Vaughan, C., et al., 2018. Surveying climate services: What can we learn from a bird's eye view? Weather Clim. Soc. https://doi.org/10.1175/WCASD-17-0030.1.
Watts, N., et al., 2020. The 2020 report of The Lancet Countdown on health and climate change: responding to converging crises. Lancet 6736 (20). https://doi.org/10.1016/s0140.
WHO/WMO. (2016) *Climate Services for Health: Improving public health decision-making in a new climate*. Eds. J.Shumake-Guillemot and L.Fernandez-Montoya. Geneva.
Wright, C. Y., Chersich, M. and Mathee, A. (2019) National health insurance and climate change: Planning for South Africa's future. *South African J. Sci.*, 115(910), pp. 9–11. 10.17159/sajs.2019/5800.
Wright, C.Y., Mathee, A., Garland, R.M., 2014. Climate change, human health and the role of environmental health practitioners. S. Afr. Med. 104 (8), 518.
Yin, R., 1993. Applications of case study research. Sage, Thousand Oaks, CA.