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CLIMATE CHANGE RESPONSE STRATEGIES AND IMPLICATIONS ON SUSTAINABLE DEVELOPMENT GOALS IN MUTIRIKWI RIVER SUB-CATCHMENT OF ZIMBABWE

Chenjerai Ziti[1], Lazarus Chapungu[2*], Nhamo Godwell[2]

[1]Great Zimbabwe University, Department of Physics, Geography and Environmental Science, Masvingo, Zimbabwe
[2]University of South Africa, Exxaro Chair in Climate and Sustainability Transitions,
Preller Street, Muckleneuk Ridge, Pretoria, South Africa
*Corresponding author lchapungu@gmail.com

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Abstract

Sub-catchment level water sector response strategies to climate change in Zimbabwe have not been adequately analyzed to determine their impact and connectedness with the Sustainable Development Goals (SDGs). In this study, the mixed methods research design is used to examine the implications of water sector climate change response strategies (CCRS) on SDGs in Mutirikwi sub-catchment in Masvingo, Zimbabwe. Results show that the climate is changing, with a statistically significant ($p = 0.031$; $\alpha = 0.05$) increase in the annual mean temperature and a declining rainfall trend, though not statistically significant ($p=0.753$; $\alpha = 0.05$). Views from local communities and stakeholders confirm the existence of climate change. There is a deluge of response strategies to the changing climate, including borehole drilling, roof rainwater harvesting, surface storage, water reuse and water transfers. These strategies have directly contributed to the achievement of SDG 6 (Clean Water and Sanitation), SDG 11 (Sustainable Settlements), and SDG 13 (Climate Action). They have also indirectly contributed to the achievement of SDG 3 (Health), SDG 5 (Gender), SDG 9 (Infrastructure) SDG 12 (Sustainable Consumption) and SDG 15 (Life on Land). The study concludes that there is an inextricable link between CCRS and SDGs. However, implementation of the response strategies is riddled with challenges that are threatening the sustainability matters. There is a need to design community-driven response mechanisms synergized with national and international climate adaptation initiatives to ensure sustainability of the strategies through guaranteed policy and resource support from the national government and non-governmental agencies.

Keywords: water sector, climate change, SDGs, response strategies, sub-catchment

INTRODUCTION

Climate science demonstrated beyond doubt that the climate system is not constant (Gulev et al 2021). The current changes in the system are marked by an increase in the frequency and magnitude of weather-related events such as heatwaves, droughts, tropical cyclones, thunderstorms, and storm surges among others (The Royal Society 2020; Chapungu 2020; Chapungu and Nhamo 2016). The changes are also evident in the altered patterns and oddity of climatic elements such as temperature, precipitation, humidity, solar radiation, wind, cloud cover and atmospheric pressure (Gulev et al. 2021; Change Climate 2021). Accompanying these changes are a deluge of negative consequences, which have affected ecosystems, economies, and human society in many ways (UNESCO and UN-Water 2020).

Water is the principal medium through which climate change impacts are felt in all sectors and facets of life (United Nations Water 2021; UNESCO and UN-Water 2020). Some impacts can be felt on food security (SDG 2), human health (SDG 3), energy production (SDG 7) and livelihoods in general (UNESCO and UN-Water 2020). Related to these are social inequalities (SDG 10), unrests, forced migrations, and conflicts (SDG 16), among other vices. In fact, virtually all facets of life are intrinsically connected with water (SDG 6) in its various forms. Thus, water stands as the decisive link to the global commitments towards a sustainable future. Consequently, effective water resources management becomes the fundamental cog for the achievement of the 2030 Agenda for Sustainable Development and its 17 SDGs (Singh et al 2020; United Nations General Assembly 2015).

Adding to the woes in the water sector, global water use has increased by a factor of 6 during the last century and continues to increase steadily at approximately 1% per annum (Ritchie and Roser 2017). While this has been largely attributed to the global population growth, economic development and shifting consumption patterns, climate change has exacerbated the situation. Consequently, more regions will become water stressed in the future, punctuated by shifts in seasonal availability of physical water (Ritchie and Roser 2017).

In view of the perpetual consequences faced by the water sector due to climate change, the need for research and policy attention cannot be overstated.

Country-specific catchments and sub-catchments are obliged to incorporate strategies to adapt to and mitigate the effects of climate change (Singh et al 2020; Brazier 2015). Given the need to advance the sustainable development agenda, the examination of the implications of climate change response strategies in the water sector on SDGs is critical. This is so because water serves a connecting and facilitatory role within the 2030 Agenda. The SDGs are unachievable if the water sector is left out of the development matrix. In fact, if the trade-off between water conservation and SDGs is ignored in the climate adaptation strategies, the attainment of "Zero Hunger" (SDG 2), "Sustainable Cities and Communities" (SDG 11), and "Life on Land" (SDG 15) goals, will be jeopadized (SIWI 2017; Dombrowsky et al 2016; United Nations General Assembly 2015).

In context of the vitality of the water sector within the development matrix, and the prevailing and projected impacts of climate change on the sector, an analysis of the sector's response strategies within the context of the global development agenda merits attention. It is in view of this need that the current study examines the climate change response strategies' implications for SDGs in the water sector in the Mutirikwi sub-catchment of Zimbabwe. Important questions posed in this regard are as follows: Is there evidence of climate change at sub-catchment level? What are the water sector responses or adaptation strategies to the impacts of climate change at sub-catchment level? What are the implications of the responses at sub-catchment level on the attainment of the SDGs?

LITERATURE REVIEW

The water sector is still to cope with the changing climate, especially in developing countries (Gulev et al 2021). Certainly, projected impacts will affect water availability and use and consequently, its management. Globally, the effects of climate change on water resources are felt directly and indirectly in the socioeconomic and biophysical environments (Conway et al 2015). The impacts of climate change on the water sector in Southern Africa are well documented (Scholes and Engelbrecht 2021; Rankoana 2020; Kusangaya et al 2013). The poverty and low adaptive capacity of the region increase its vulnerability. Africa lacks climate literacy, which is the skill and proper implementation as well as timely information dissemination for effective responses to climate change.

Responding to the phenomenon requires a scenario-based holistic approach. Realizing this need, SDG 13 advocates urgent action to combat climate change by helping more vulnerable regions. Climate change responses are actions taken to adjust to the impacts of agents of change and to reduce effectively consequential vulnerability (NASA 2021). The water sector responds to climate change through adaptation (Chapungu and Sibanda 2015). UNESCO and UN-Water (2020) noted that water-related response strategies should offer economic, social and environmental co-benefits. There are trade-offs between climate change and water-related response strategies. Some measures can directly affect water resources by increasing or decreasing water demand, and it is important to be aware of this two-way relationship when developing and evaluating choices (UNESCO and UN-Water 2020).

Studies on adaptation in the water sector can be noted in some rural parts of China (Tianjin), India, South Africa, Somalia and Ethiopia (Zhou 2013; Weldegebriel and Gustavsson 2017; Muchuru and Nhamo 2019). Failure to consider the role of water in all activities, can reduce the effectiveness of the strategy and increase the risk of maladaptation or complete failure (UN Water 2021). The goal is to use the most sustainable strategies to maximize benefits and system effectiveness, while minimizing costs and trade-offs (United Nations Water 2021). Ricalde et al. (2022) note that non-structural responses can offer positive results under uncertain conditions compared to structural responses which have higher irreversible costs. Therefore, adaptation remains a key driver in responding to climate change in the water sector.

What then is adaptation? Adaptation is any adjustment – passive, reactive, or anticipatory, that can respond to anticipated or actual consequences associated with climate change (NASA 2021). However, adaptation takes different definitions depending on the subject under study. The adopted definition of climate change adaptation in this study is that of the Intergovernmental Panel on Climate Change (IPCC), which considers adaptation as the process of adjustment to actual or expected climate change and its effects. In human systems, adaptation seeks to moderate or avoid harm or to exploit beneficial opportunities (United Nations Water 2021). Adaptation strategies are determined by the degree of vulnerability, magnitude of change, and adaptive capacity of the system to the climate stimuli of the physical systems, natural ecosystems, socioeconomic conditions, and institutional aspects of the country.

For a long time, Zimbabwe had no specific and comprehensive policy or response framework to climate change impacts. The National Climate Change Response Strategy was realized only in 2012, yet Zimbabwe has been active in the international arena as it signed and ratified the UNFCCC in 1992 and agreed to the Kyoto Protocol on Climate Change in June 2009. The country is also fully supportive of and has ratified the 2030 Agenda for Sustainable Development and its 17 intertwined SDGs. It is not surprising to note that to date, Zimbabwean cities such as Harare, Bulawayo, Gweru, Kadoma, and Masvingo face acute water challenges (Mapetere 2019). Some towns like Norton are experiencing shortages despite being closer to large water reservoirs. It is correct, therefore, to state that Zimbabwean cities are choked with water woes in the midst of plenty yet it is striving to have sustainable cities and communities (SDG 11) through the provision of clean water and sanitation (SDG 6) (Kanyepi and Tanyanyiwa 2021). The Zimbabwean water resources are still to be fully developed. There are serious weaknesses in the present water resources planning and management procedures especially regarding the achievement of SDGs. As a result there is a lack of understanding of and institutional facilities for dealing with water in its broader environmental and cyclical context (Kanyepi and Tanyanyiwa 2021).

Climate change's effects on Zimbabwe's sustainable development are mostly sectoral, focusing on agriculture, health, water and energy. As a result, climate change responses will be sector-based in the future, but there is insufficient scholarship in the water sector (Chanza and Jakarasi 2020). Furthermore, when the water sector is considered, it is engulfed in agriculture assessments and related SDGs, leaving the catchment studies with no context. Given this backdrop, Mwadzingeni et al. (2021) concentrated on smallholder irrigation farmers in the Kwekwe, Gweru, and Shurugwi areas. These districts are included in the Upper Runde sub-catchment (ZINWA 2022). In a rain-fed agro-based economy, great emphasis is placed on food security (SDG 2) and making human settlements safe, inclusive, resilient, and long-term (SDG 11) (Chanza and Jakarasi 2020). If the SDGs are to be met, climate change initiatives must focus on enhancing water security (Mwadzingeni et al 2021).

One of the climate change adaptation strategies, in-field water collection, has been established as a viable option in Gwanda under the Mzingwane catchment (Ndlovu et al 2020). Harvesting water is an important reaction mechanism for guaranteeing water security. By minimizing crop production vulnerability to climate fluctuation and thus boosting crop yield, the adaptation method enhances water conservation and management techniques. Water harvesting in the fields entails a variety of soil and water conservation measures aimed at improving rainwater infiltration (Tolossa et al 2020). While the strategy focuses on crop productivity, it also aids in the achievement of SDG 15 by restoring and encouraging sustainable agriculture and ending land degradation. The implication of soil erosion in the Runde basin falls within the moderate to insignificant erosion risk category (Mutowo and Chikodzi 2013).

Two studies in Mzingwane and Save catchments, have modelled the possible impacts of climate change. In addition, ten downscaled climate models have been applied to the “Save Catchment” to understand adaptation actions for dry land agriculture and livestock farming in Chiredzi district. SDG 2 is the main focus of these studies. Through an optimal model on water resource allocation in the southeast lowveld, Muririkwi sub-catchment has been held at tangent. Studies of the water sector in Masvingo are limited and confined to the Masvingo urban area (Mapetere 2019; Mhiribidi et al 2018). There is insufficient attention to water resources on issues concerning catchment conservation, water harvesting and environmental impacts. However, Zimbabwe’s water sector has started to respond to climate change through the construction of dams (initially for agricultural purpose), policy reforms, establishment of catchment and sub-catchment councils, and the National Water Resources Management Strategy.

MATERIAL AND METHODS

The study was conducted in Mutirikwi sub-catchment (MSC) located in the Runde catchment in Masvingo province (Fig. 1).

The sub-catchment was established as per mandate of the reformed Water Act of 1998 (Mutirikwi Sub-Catchment Council 2022). The sub-catchment drains from the north at Serima stretching to Triangle covering districts such as Chiredzi, Gutu, Masvingo, and a small part of Zaka. Using the 2012 census as baseline data, the three districts of Chiredzi, Gutu and Masvingo have a population of 808391 (Zimstats 2012). From the source to the mouth, the average yearly temperature rises, ranging from 18°C in Chartsworth to 23°C in Triangle. Within the catchment, there is also a spatial difference in rainfall, with Gutu receiving more rain than Chiredzi. The Chivaka, Munendi, Mutirikwi, Mucheke, Popoteke, and Shagashe rivers all drain the region. The Lake Mutirikwi and Bangala dams are substantial surface water storage facilities, with Lake Mutirikwi being the country's second-largest inland water body after Tokwe Mukosi

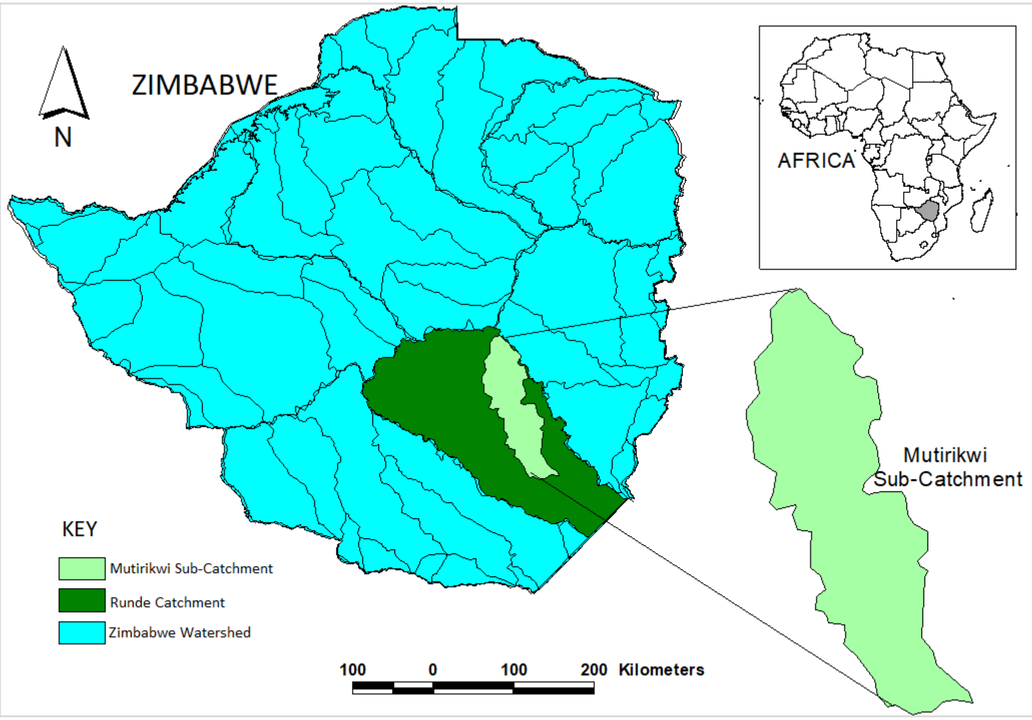

Fig.1 Map of Mutirikwi sub-catchment

(Chazireni and Chigonda 2018). Magudu, Mushavi, and Tugwane are three other private water reservoirs. The total yield of Mutirikwi, Bangala, and Nyajena is 519 billion litres, with a documented commitment of 437 billion litres (ZINWA 2022). In a 3900 km^2 area, there are 162 registered surface water users and 97 registered groundwater users (Mutirikwi Sub-catchment Council 2022). The catchment also depends on groundwater.

Research design

The mixed-methods research design was used as the strategy for both data collection and analysis. This model uses both quantitative and qualitative data collection and analysis methods that play a complementary role in the inquiry process (Kivunja and Kuyini 2017). The variables considered under this design are shown in Figure 2.

As shown in Figure 2, qualitative and quantitative data were integrated to interpret patterns and dynamics associated with the climate change response strategies in the water sector within the sub-catchment. The design involved a community participatory approach in the collection of data to explore the different climate change response strategies being used in the sub-catchment. The approach involved the community as active participants in the data collection process. Organizational representatives, researchers and community members contributed their diverse and specialized expertise in collectively building a variables database that addresses research questions. This approach is regarded as effective in increasing knowledge and understanding of a specific study phenomenon and helps in integrating knowledge with interventions and policy tools that improve the quality of life (Rankoana 2020).

Sampling and data collection

Key informant interviews

A total of 38 key informant interviews provided qualitative data for the study. The study population comprised individuals above 18 years of age whose place of residence is Mutirikwi sub-catchment. This included males and females selected through a combination of purposive and convenience sampling approaches. Purposive sampling was rather judgmental, selective or subjective (Mujere 2016; Pohlert 2017). Occasionally known as grab or opportunity sampling, the method is a non-probability sampling method that involves the sample being drawn from that part of the population that is close to the researcher.

A participatory approach to data collection was adopted, where the communities actively assisted with identifying individuals who had the relevant information for the study. Ishtiaq (2019) noted that in a participatory study, the opinions and dictates of study participants take centre stage. Through this process, water committee members, headmen, and influential individuals were selected purposively and conveniently to participate in interviews. In addition to this, Zimbabwe National Water Authority (ZINWA) staff members, Mutirikwi sub-catchment council staff members, Masvingo Rural Development council members, Chiredzi Rural District council members as well as Masvingo City council members were purposively selected to participate in the study due to their expertise and involvement in the water sector.

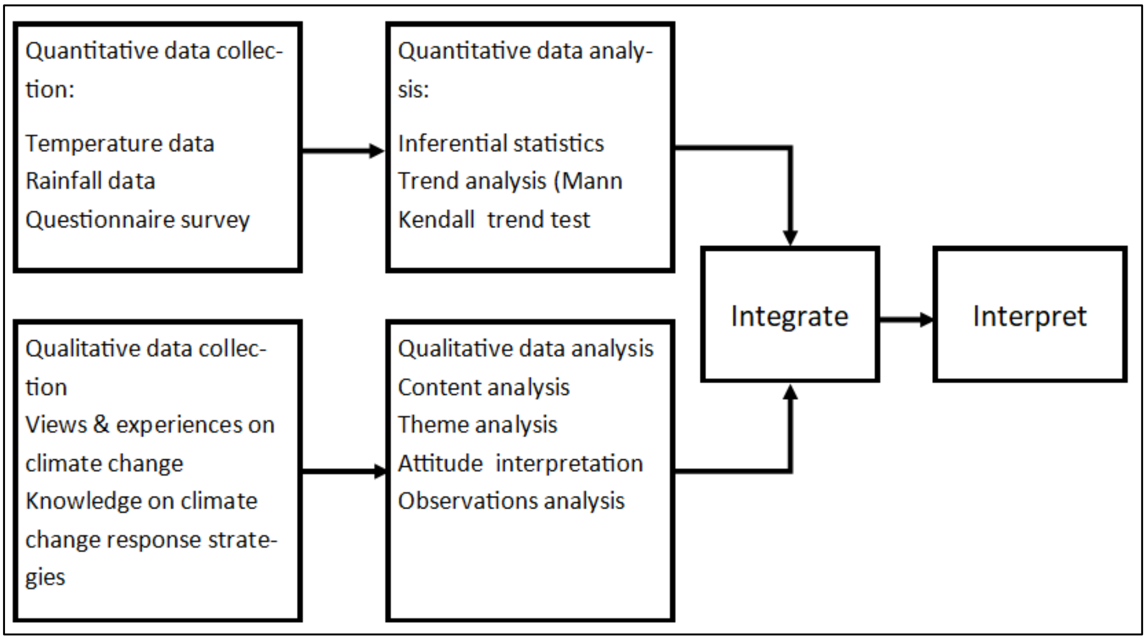

Fig.2 Mixed methods design. Source: Authors, adapted from Chapungu (2020)

Questionnaire surveys

Questionnaires were used to collect data from the residents of the Mutirikwi sub-catchment (n=397). The questions from several authenticated and peer-reviewed surveys served as the basis for the development of the data gathering instrument. There were 31 questions in total, divided into the following 4 sections: Section A- demographic data, Section B- awareness of climate change and SDGs, Section C - impacts of climate change on water resources and Section D - response strategies. The questionnaire completion rate was 96%.

Climatic variables

Long-term meteorological data were obtained from the four weather stations run by the Meteorological Service Department of Zimbabwe, namely Makoholi, Masvingo, Zaka and Buffalo Range. These data were verified through comparison with another set of data obtained from the NASA Power portal https://power.larc.nasa.gov/data-access-viewer/. Temperature-related variable data spanning the 1984–2020 period and precipitation-related variable data spanning the 1969–2021 period were used. The data were used to determine the climatic trends within the sub-catchment.

Data analysis

Data analysis was performed through exploratory and confirmatory approaches. Temperature and precipitation variable data were first tested for normality using the Kolmogorov-Smirnov test. Subsequently, the non-parametric Mann-Kendal (M-K) test was performed to determine the trend in temperature and precipitation data over time using XLSTAT 2020. The M-K test detects monotonic trends in series of hydro-meteorological data (Pohlert, 2017; Chapungu and Nhamo 2021). Kocsis, Kovács-Székely and Anda (2020) noted that the test has the prowess to deal with missing values, seasonality and values below detection limit. The computation of the M-K test is shown in equations 1–3 below:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn\ (Xj - Xk) \quad (1)$$

Where S is the Kendall score. sgn (x) = {1 if x > 0, 0 if x = 0, -1 if x < 0} (Mann, 1945)

The variance of S is calculated from equation 2

$$Var\ (S) = \frac{1}{18}[n(n-1)\ (2n+5) - \sum_{p-1}^{g} tp\ (tp-1)\ (2tp+5)\ ] \quad (2)$$

Where g is the number of tied groups and tp is the number of observations in the p th group.

After computing the variance, the Z value (Zmk) is computed in equation 3.

$$Zmk = \frac{s-1}{\sqrt{VAR(S)}}\ if\ S > 0$$
$$= 0\ if\ S = 0 \quad (3)$$
$$= \frac{s+1}{\sqrt{VAR(S)}}\ if\ S < 0$$

A positive M-K statistic ZMK denotes a positive change in the variable trend while a negative ZMK indicates a decreasing trend (Tehrani et al 2021). The values greater than 1.96 and smaller than −1.96 indicate significant changes at 95% confidence level.

Qualitative data was analysed by way of grouping thematic content and interpreting observations and content in a systematic manner before integrating with quantitative data.

RESULTS

Climate change in Mutirikwi sub-catchment

The Mann-Kendall trend test shows an increasing, statistically significant (p= 0.031, α = 0.05) trend in annual mean temperatures between 1969 and 2021 in the sub-catchment, a condition that may contribute to the proliferation of dry conditions in the catchment. Figure 3 shows the temperature trend for Mutirikwi sub-catchment.

As shown in Figure 3, the annual mean temperature in the sub-catchment significantly increased between 1969 and 2021, depicting a changing climate in Mutirikwi sub-catchment, which necessitates climate action within the water sector, through various response strategies. As the average temperatures increase over time, there is high variability depicted by the fluctuating mean annual temperatures as shown in figure 3, with consecutive years having extremely different means. For example, whilst the mean annual temperature for 2017 was close to 20.20°C, by 2019, the mean temperatures had increased to 21.79°C. The variability appears to also increase with time, an indication that climatic conditions have not been constant in the sub-catchment.

Precipitation shows a slightly decreasing trend over time. The Mann Kendall trend test shows that the trend is not statistically significant (p = 0.753, α = 0.05) as shown in Figure 4.

Figure 4 indicates that there is no significant change in precipitation over time. However, lack of a statistically significant trend of total seasonal precipitation does not imply that there is no climate change given that the other precipitation variables such as precipitation of the warmest quarter (Chapungu et al 2020; Mutimukuru-Maravanyika et al 2022), monthly mean precipitation and total annual precipitation (Chapungu 2017) within the same catchment have been shown as significantly changing. In addition, the total seasonal precipitation is also showing a declining trend, which might not be statistically significant but has compound environmental feedbacks.

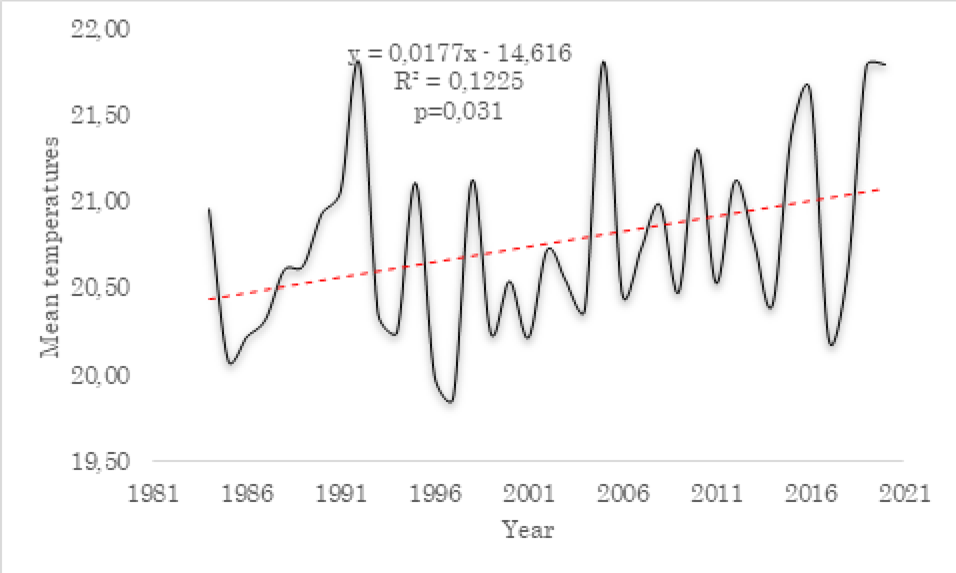

Fig.3 Mean annual temperatures in Mutirikwi sub-catchment.
Source: Authors, data from Nasa Power https://power.larc.nasa.gov/data-access-viewer/

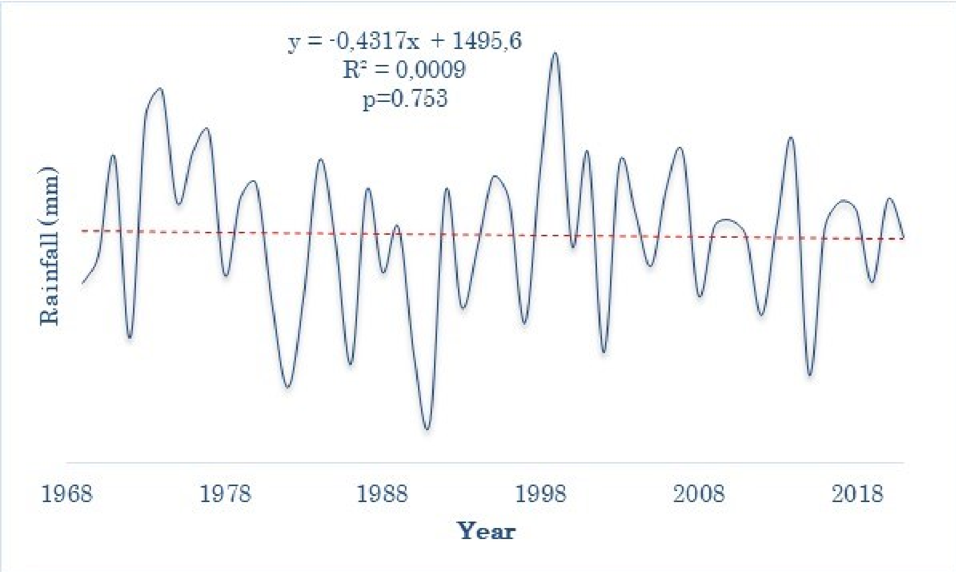

Fig.4 Mean annual rainfall trend in Mutirikwi sub-catchment.
Source: Authors, data from Nasa Power https://power.larc.nasa.gov/data-access-viewer/

The results have also shown that there is high inter-annual precipitation variability in Mutirikwi sub-catchment. Figure 5 shows deviation of precipitation from the mean over time. Whilst there has not been a statistically significant decrease in precipitation, the rate of variability is high as shown by the significant deviation from the mean.

The years with greater deviation, showing a decrease in precipitation coincide with the 10-year drought cycles. As shown in Figure 5, 1971-72, 1981-82, 1991-92, 2001-2002 droughts are clearly depicted by very low precipitation and a greater deviation from mean rainfall in Mutirikwi sub-catchment. Some years experienced above average rainfall and the deviation from the mean is huge.

In addition to statistical data, qualitative data obtained through interviews and some sections of the questionnaire survey confirm that climate change is a reality in the sub-catchment. Figure 6 shows the perceptions of the people who participated through the questionnaire survey regarding specific temperature and precipitation related variables.

As shown in Figure 6 more than 75 percent of the respondents strongly agreed with the notion that temperatures are increasing over time. Close to 80 percent also strongly disagreed with the perception that temperatures have remained constant. This confirms the findings obtained from statistical analysis of secondary data, which show an increasing trend of temperatures over time. Most of the respondent (more than 75%) concur with the notion that precipitation is decreasing while 80 percent strongly believe that more extreme events have been happening within the catchment.

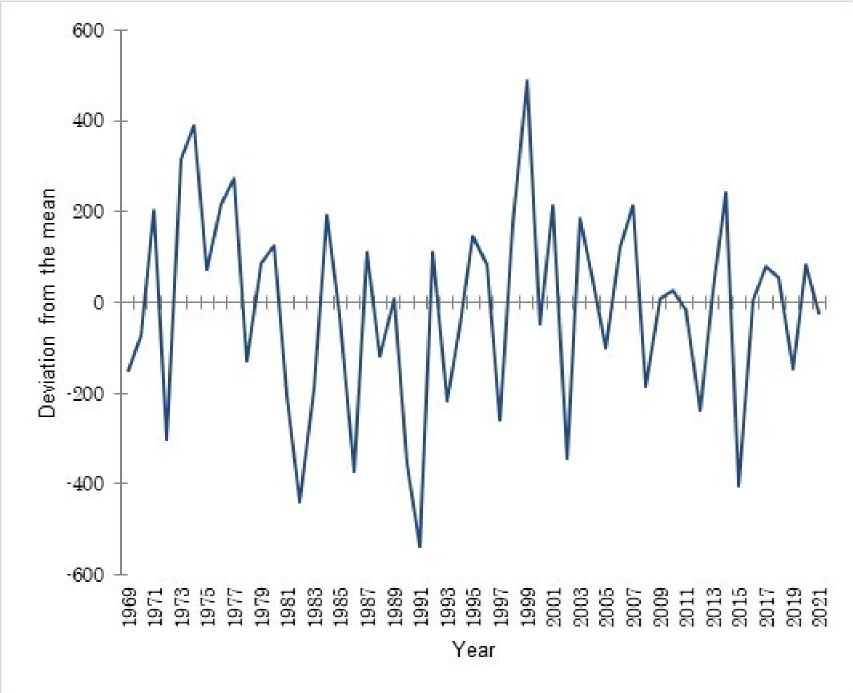

Fig.5 Precipitation variability in Mutirikwi sub-catchment council.
Source: Authors, data from Nasa Power https://power.larc.nasa.gov/data-access-viewer/

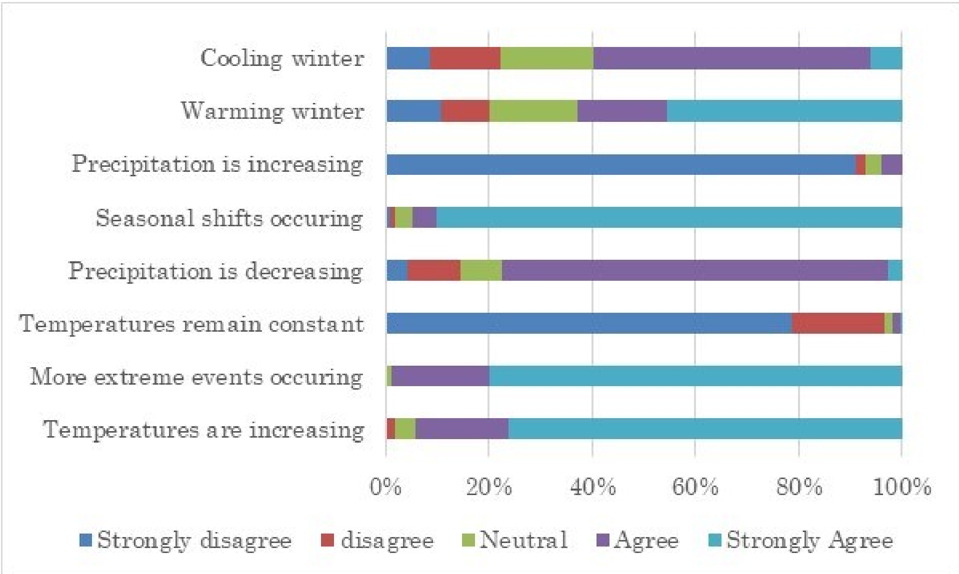

Fig.6 Perceptions regarding climate change

Climate change response strategies in Mutirikwi sub-catchment

The results indicate the existence of a plethora of planned and autonomous climate change response strategies in Mutirikwi sub-catchment's water sector. Nine of the strategies (Table 1) have direct and indirect influence on the achievement of SDGs. The strategies can be categorised into six typologies, namely diversification of water supply, groundwater recharge, preparation for extreme weather events, resilience to water quality degradation, storm water control and capture and water conservation (Table 1).

As shown in Table 1, most of the strategies can fit into more than one typology as they contribute to more than one aspect of climate change adaptation. Consequently, the strategies have effect on more than one SDG. For example, rainwater harvesting provides an additional source of water for both domestic and non-domestic uses, thereby promoting diversity of water sources. At the same time, the harvested rainwater is used when extreme events such as heat waves occur, to irrigate water-stressed garden crops or perform any function associated with the impacts of heat stress. As indicated earlier, the response strategies have implications on progress towards the achievement of SDGs. For example, rainwater harvesting contributes towards improved access to clean water and sanitation, consequently leading to progress towards SDG 6, which proclaims the need to improve access to clean water and sanitation.

Roof rainwater harvesting

The study observed that, in the sub-catchment, about 62.5% and 68.7% of the rural and urban households respectively, practice or use the roof rainwater harvesting method. The method has been considered helpful by the respondents from both rural and urban areas because it provides clean water that can be used for domestic purposes without the need for further treatment. The method also provided safe water for domestic animal and poultry watering. The challenge faced by users is that they lack the capacity to harvest and store large volumes of water. As such, they harvest it for immediate use, lasting for less than a week. Small water containers with a capacity of less than 30 litres were observed to be the dominant materials used to harvest and store water in rural areas as well as amongst the less affluent urban dwellers. For the less affluent in urban areas, the harvested water would last for less than two days if municipal water is not available. Of the respondents who use the roof rainwater harvesting method, more than 90% highlighted seasonality as another challenge with this method. Water is only harvested during the summer season when rainfall is received and during the winter season, the method is not relevant as an adaptation option.

A few households were noted to have mega storage tanks and drums that store water for a month and beyond depending on the level of use and availability of optional water sources. The tanks are connected to a well-installed rainwater collection system which uses roof gutters. The harvested water is used for domestic purposes such as toilet flushing, washing, drinking, cooking and small livestock watering. The respondents highlighted that the harvested water received no additional treatment, besides boiling when cooking, which is regarded as a treatment process for only the amount of water to be used. Urban residents have adopted it as an alternative source when municipal water is erratic. However, the effectiveness and sustainability of rainwater harvesting from roof tops as a strategy that contributes significantly towards the attainment of SDGs is questionable in the context where the amount of rainfall received has become too erratic and significantly reduced due to the changing climate system. One respondent had this to say: "….in fact, there is no water to harvest. Our rainwater collection system from the roof top has failed to fill up a 5 000-litre reservoir at any moment in time …".

Some respondents (19.5%) highlighted the inter-seasonal and intra-seasonal variability of rainfall as the main problem affecting the reliability of this method as a sustainable way of improving access to drinking water.

Table.1 Climate change response strategies and their links to SDGs

	Typology							Implications on SDGs		Est. impact on SDGs
Response Strategy	Diversification of water supply	Groundwater recharge	Preparation for extreme weather events	Resilience of water quality	Storm water control capture	Water conservation	Level of Implementation (A=Autonomous; P= Planned)	SDGs influenced directly	SDGs influenced indirectly	10 = Very High 1 = Very Low
Rainwater harvesting	●		●		●	●	A	6, 11, 13	3, 5	7
Borehole drilling	●		●				P	6, 11, 13	3	5
Groundwater storage and harvesting	●	●		●	●	●	A	6, 11, 13	3	2
Residential water conservation	●	●		●		●	A, P	6, 11, 13	5	3
Household water storage and treatment	●	●		●	●	●	A	6, 11, 13	3	7
Efficient appliances		●	●			●	P	6, 11, 13	12, 9	5
Efficient irrigation		●	●			●	P	6, 11, 13	9, 12	3
Forest conservation				●		●	P	13, 11 ,15	6	3
User pays principle				●		●	P	6, 11	13	10

They indicated that the harvested water makes no big difference since the rainwater has become scarce due to recurrent droughts as well as uneven distribution throughout the season. Thus there are short periods of abundance and longer periods of lack, making the method insignificant. This study observed that the group of households indicating that the roof rainwater harvesting method was not an effective strategy in addressing their water woes had small storage facilities that could not last for more than a week.

However, most of the respondents (58.3%) have shown that the method has contributed significantly to water availability and sanitation improvement in the face of water shortages driven chiefly by frequent and severe droughts experienced in the catchment. Some of the respondents indicated that it is not about the quantity but the quality of water. Thus, in some households, the harvested water was reserved for drinking and cooking purposes only. This would ensure that the harvested water lasts for longer periods whilst recycled water and water from unsafe sources was used for other non-domestic purposes.

Borehole drilling

The study found that 80% of the households depended on groundwater through drilled manual and solar powered boreholes. The strategy is used at both autonomous and planned adaptation levels. Boreholes are provided by local authorities and the District Development Fund (DDF) to serve large communities, especially in rural areas. However, a significant number of the boreholes in the sub-catchment are provided by non-governmental organisations such as Oxfam, World Vision, and CARE International.

Of the 56 surveyed boreholes, 71% were concentrated in rural areas whilst the urban and peri-urban areas shared the remaining 29% of the borehole installations. Urban areas have a mix of solar powered and manual boreholes whilst in rural areas, more than 70% of the boreholes observed are manual and the remaining percentage has solar powered systems. However, the current government facility, which promotes solar powered water points may change the situation in the near future. In addition, the efforts by non-governmental organisations under the Protracted Relief Program (PRP) and other intervention programs have provided alternative water technologies such as the Elephant Pump, which uses a rope and washer system. These have gone a long way in enhancing the adaptive capacity of rural households to climate change.

Regarding the effectiveness of the borehole strategy's implications for the achievement of SDGs, the study revealed that 70% of the boreholes were accessible to households and provided adequate supplies in times when municipal water was not available. In some rural areas, some households had manual boreholes as their sole source of water. However, access to borehole water depicted by the total functionality of the surveyed boreholes, does not guarantee water security among the households as there are other factors that inhibit easy access such as distance to the water source, number of households per unit water point, and functionality of the borehole among other factors.

The borehole drilling strategy is compromised by technical challenges and lowering of the water table during the dry season and drought years. About 38% of the respondents in the rural areas indicated that their water sources usually dry up during the dry season. Technical challenges are attributed to overuse, vandalism, age, and functionality of the borehole. However, overall, there is an increase in access to water in the sub-catchment as communities and individual households as well as government and stakeholders from the NGO sector make frantic efforts to address water challenges resulting from the general increased dryness of the catchment.

Storage facilities

In Mutirikwi sub-catchment, specifically in the urban areas, households and corporate organisations have resorted to the storage of surplus municipality-supplied water to use in periods of shortages. There is a diversity of storage facilities depending on the socioeconomic status of the household. Households with better income have managed to install 5 000 litre tanks that can store supplementary water to cater for a family of 5 for 50 days on average. Most of these storage facilities are found in urban areas in the suburbs of Rhodene, Morningside, Clipsham Heights, and Hillside Extension.

However, this strategy is a preserve of the affluent owing to the cost of installing the storage facility. About 12.3% of the sampled respondents in the urban areas indicated ownership of such huge facilities. However, a significantly small segment (0.7%) of the surveyed population indicated that they often share their stored drinking water with those who do not have storage facilities. While the number of people with storage facilities is low, these facilities help in reducing pressure on the available public water points in the time of shortages.

Residential water conservation

Results indicate that the residential water conservation strategy in the form of reuse, recycle and reduce (RRR) approaches is one of the most widely adopted approaches to water conservation in Mutirikwi sub-catchment with more than 76% of the respondents indicating that they use the approach as a whole or in part. The RRR strategy involves a combination of using the water for the second time for the same purpose, using water for another purpose after it has been used for its primary use, and using as little water as possible to perform a specific function. Respondents indicated that, as a response to water shortages, they use grey water for watering their nutrition gardens, flushing toilets, and cleaning floors as well as washing cars. This is done consistently when the users go for days without municipal tap water. However, the practice is abandoned when clean municipal tap water is available.

The use of water-efficient appliances and fixtures such as dishwashers, washing machines, water-efficient toilets, showerheads and faucets helps 19.8% of the urban households in Mutirikwi sub-catchment to reduce the quantities of water used for specific purposes and contributes to enabling their adaptive capacity to erratic water supplies driven indirectly by climate change. This is in line with observations by Mapetere et al (2019) that water-efficient appliances are a necessity if water conservation is to be realised. Such practices contribute to the attainment of SDG 6 through the conservation of much needed water resources.

Surface storage

The study established that 30% of the participants acknowledged their dependence on surface water. This strategy involves harnessing of groundwater or surface water through natural or artificial reservoirs. It was observed that surface reservoirs in communal lands are important for watering livestock, gardening and brick molding. Individuals with surface storage were noted in Morningside and Triangle. In Triangle, the harvested wastewater from sugar cane plantations is used for horticulture in the resettlement area adjacent to the sugar estates. The strategy is practiced in low-lying areas where excess water is drained out of the sugar cane fields. The sustainability of the strategy is compromised by reduced rainfall received in the area and its dependency on controlled flood irrigation methods. However, the stored water can help to sustain crops leading to better yields even during years of drought. This has direct implications for SDGs 1 (No Poverty), 2 (Zero Hunger), and 3 (Good Health and Wellbeing). However, the respondents noted the challenges of siltation and high evaporation rates that would deplete the surface water storage before any substantial use can be derived.

Inter-basin water transfer

Interviews with water resources managers from Chiredzi Rural District Council Environmental Engineering Department and Ministry of Agriculture, Mechanization and Irrigation Department and Mutirikwi Sub-catchment Council revealed that water transfers allowed water deficit regions to acquire it from regions with excess. In the catchment, it is noted that the water transfer strategy is practiced at major catchment levels, that is from Save catchment to Runde catchment. Within the catchment users are allowed to use water from other rivers. Interviews established that inter-basin transfers per se was not practiced in the catchment; but rather MSC distributed or "fed" water into the Chiredzi sub-catchment and Lower Runde sub-catchment when it had received better rainfall than the other catchments. The strategy has managed to provide water for irrigation to farmers in Triangle and Hippo Valley, which draw their water from the three catchments. For the fact that inter-basin transfer is practiced at major catchment levels, water woes for the households have not been fully addressed. However, the strategy managed to remedy hydro-ecological imbalances caused by climate change.

Diversified farming and land use change

Interviews maintained that livestock farmers in the catchment migrated seeking for pastures. It is revealed that there is a need to destock aged cattle and adopt small livestock like goats. However, plant species have not been spared by the phenomenon. Changes in climate variables can be matched to a decrease in vegetative species richness and a change in phenology and diversity (Chapungu and Nhamo 2016). Some plant species changed in phenology, abundance, and distribution as they succumbed to the environmental changes emanating from climate change. In the Morningside area, a peri-urban settlement, it was identified that in the 1980s, locals were only allowed to have dairy cattle, which grazed on the individual's premise. However, due to a decline in rainfall and water for irrigation, the locals adopted drought-resistant livestock. Tree conservation is limited within the catchment. Extensive fields have been opened up near Buffalo Range for sugar cane production together with resettled farmers who are opening up new fields. In this case there is more of a need to intensify underutilised land than to open up new fields. Agro-forestry is practiced at limited rate in resettled and communal areas. High temperatures in the catchment causes planted and juvenile trees to die. The issue of tree loss is aggravated by the droughts which affect vegetation regeneration.

Implications of climate change response strategies for SDGs: Community perceptions

Results on communities' perceptions regarding the implications of climate change response strategies on Agenda 2030 are presented in Figure 7.

Figure 7 shows that residential water conservation strategies through the RRR approach is strongly perceived (93%) as the most important strategy regarding the achievement of SDGs in Mutirikwi sub-catchment. About 91% strongly perceive borehole drilling as contributing more to Agenda 2030, making it the second highest ranked strategy, especially regarding the provision of clean water and sanitation. This is followed by roof rainwater harvesting (81.2%) which was indicated as important in providing supplementary clean water for domestic purposes and small-scale commercial projects. Overall, all the interventions meant to adapt to or mitigate climate change are contributing directly or indirectly to the achievement of SDGs in the Mutirikwi sub-catchment.

Through the attribute scoring method, this study has established that the climate change response strategies in the water sector in Mutirikwi sub-catchment have contributed significantly to progress towards the achievement of SDGs and their targets over time. Figure 8 shows an increase in water access per household over time, meaning that there is progress towards SDG 6 over time. Between 1990 and 2018, the average water access score within the sub-catchment has increased.

As shown in Figure 8, the probability of a household in the sub-catchment having access to adequate drinking water from any source in 1990 was 25%. This increased over time and in 2018, the probability was about 64%. Given the trend, it can be estimated that currently (2022) it sits at +/- 70%. As also shown in Figure 8, more people

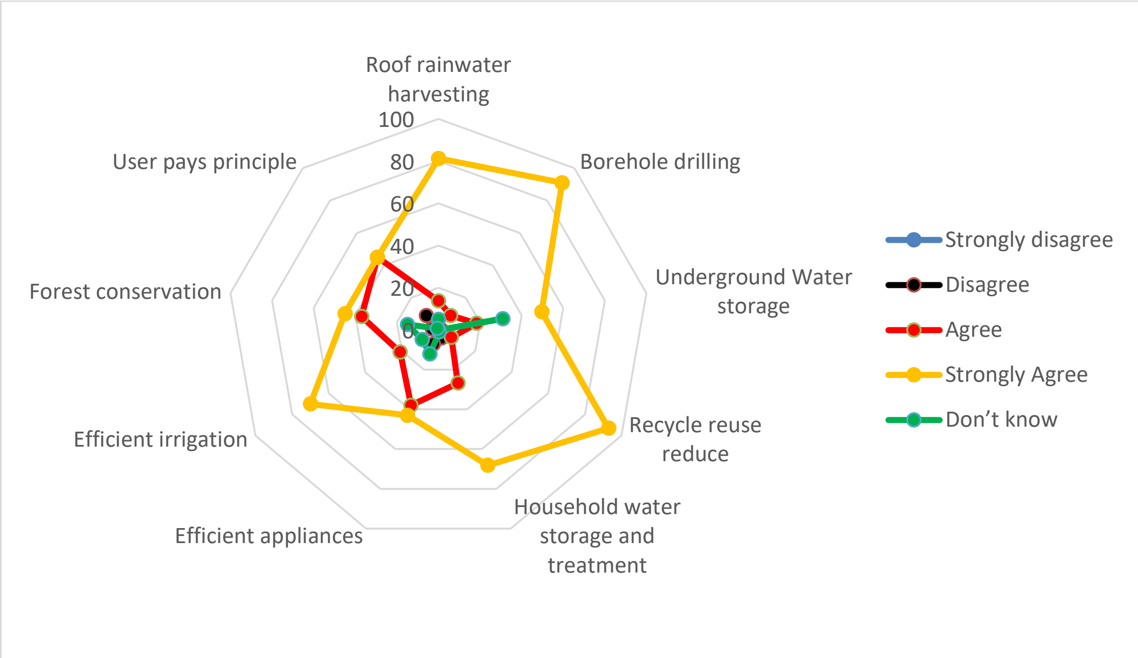

Fig.7 Perceptions on the implication of CCRS on SDGs

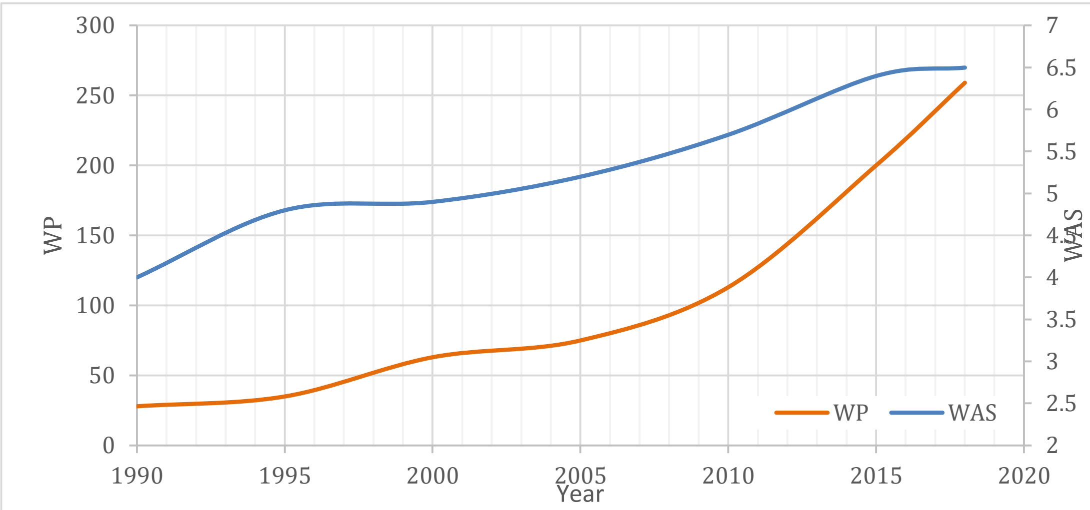

Fig.8 Average water access score (WAS) and the number of water permits (WP) in Mutirikwi sub-catchment between 1990 and 2018.

have access to surface and groundwater reservoirs through water permits that they obtained. The total number of water permits (WP), for both groundwater and surface water, is estimated at 259 (groundwater = 97; surface water = 162). The increasing number of water permits over time is indicative of government and stakeholder efforts to achieve SDG 6. However, key informant interviews revealed that the driving force behind the solicitation for water permits are the frequent and severe dry spells driven by the changing climate system. Farmers around the sub-catchment tend to respond through soliciting water permits in order to supplement the erratic rainfall in the region. Similarly, other climate change response strategies such as rainwater harvesting, conservation, and water storage, among others, have also contributed to the increase in the average water access probability per capita household over time. Thus, it is the contribution towards the achievement of SDG 6 and related goals such as SDG 11, SDG 13 and others that directly benefit from the spill-over effects.

DISCUSSION

The results provide evidence of a changing climate in Mutirikwi sub-catchment council. This is depicted by the significantly increasing mean annual temperatures over time. The sub-catchment lies in a region where increasingly warming winter seasons and an increase in the frequency of seasons with extreme temperature-related events such as heat waves have been observed. The statistical results were confirmed by respondents who indicated that, over the years, they have noticed a general increase in temperatures associated with increased dryness and water scarcity in the sub-catchment. These results are consistent with results of previous studies in areas within the proximity of Mutirikwi sub-catchment. For example Chapungu et al (2020); Mudzengi et al (2021) and Chapungu and Nhamo (2021) observed increasing trends in various temperature-related variables in Masvingo province, within which Mutirikwi sub-catchment exists.

The changing climate, as shown in this study and consistent with results from previous studies within the catchment, orchestrates a deluge of negative ramifications on the water sector within the sub-catchment as manifested by the effects on water availability, agricultural production, health and sanitation, among other facets of life. More than one billion people across the world have no access to clean water and sanitation while an increasing number of regions continue to face water stress and sanitation challenges, especially in Africa (Abrams et al 2021; Siderius et al 2021). In Africa, 14 countries have, for more than a decade, experienced water stress and 11 others are projected to join the list by 2025 (Abrams 2021). The water challenges are mainly attributed to the changing climate system (Kalele et al 2021; Abrams et al 2021). Thus, response strategies in Mutirikwi sub-catchment contribute to the efforts being pursued by policymakers and stakeholders in the water sector to achieve SDGs targets.

The need for climate change response strategies has been recognized. Consequently, a cocktail of measures has been put in place at individual, family, corporate, and government levels to try and reduce the impact of climate change in the water sector. The measures are either autonomous (individual and family) or planned (corporate and government) mechanisms. Apparently, response strategies are developmental in nature. Directly or indirectly, they will have an influence on national, regional, as well as the global development agenda. Similar studies that focused on the agricultural sector also observed that climate change response strategies can significantly contribute towards attainment of SDGs, for example, Magesa et al. (2023) observed positive implications of farmers' adaptation strategies to SDGs 1 and 2 in Tanzania. Implications of climate change response strategies on SDGs can be observed within the water sector in the Mutirikwi sub-catchment. Similarly, Hernandez et al. (2020) found synergies between energy sector climate change adaptation and mitigation strategies having positive implications for SDGs.

The Mutirikwi sub-catchment is a case example of what other communities are doing in Zimbabwe and several parts of Southern Africa. Thus, as communities strive to adapt to the changing climate, they found themselves implementing projects that assist in the achievement of sustainable development goals. What lacks is the documentation of the progress made in the localization of SDGs in the water sector. Hernandez et al (2020) allude to the lack of knowledge on the energy sector-SDGs nexus and this seem to be the case with water sector-SDGs nexus.

There is a need for strong policy and strategic framework for supporting climate resilience building in the water sector as this has culminated in significant progress towards the achievement of SDGs at sub-catchment level. An effective framework would include assigning responsibilities to key stakeholders at sub-catchment level towards the achievement of a common goal of building resilience of communities to climate change impacts.

CONCLUSION

The study sought to assess the climate change response strategies in Mutirikwi sub-catchment with a view to ascertain its implications for the attainment of the SDGs. The study shows that the climate system is indeed changing, with a significant increase in temperature variables and a decreasing, though not significant, trend in precipitation variables. The results are consistent with available evidence from studies in the mega-basin in which the catchment lies. The consequences of climate change are evident in the catchment as espoused in several studies. The water sector has directly and indirectly responded to the impacts of climate change through various strategies, which include roof rainwater harvesting, surface water storage, and residential water conservation, among others. An important observation emerging from this study is that the collective influence of adaptation measures used by households and corporates is contributing to an increase in per capita safe water access over time. The increase in safe water access has implications for the achievement of SDGs, specifically SDG 6, SDG 11, and SDG 13. Progress towards the attainment of these SDGs contribute to the achievement of SDG 1 (No Poverty), SDG 2 (No Hunger) and SDG 3 (Good Health and Wellbeing). Thus, this study concludes that climate change response strategies in the Mutirikwi sub-catchment play a double pivotal role of enhancing community resilience to the impacts of climate change and contributing to the achievement of the global development Agenda 2030. The key take-home message is that reducing both the impacts and drivers of climate change will require substantial changes in the way communities use and reuse the earth's limited water resources as learnt in the case of Mutirikwi sub-catchment.

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Authors' contributions: CZ conceptualised the study, collected and analysed part of the data and produced the first draft of the manuscript; LC re-conceptualised the study, collected and analysed part of the data and revised the first, second and third drafts of the manuscript, GN reviewed and edited the manuscript to improve its quality.

Data availability: The data that support the findings of this study may be made available on request from LC. The data are not publicly available because of the agreements made with the participants.

Declarations

Competing interests: The authors declare that they do not have competing interests.

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Consent to participate: Consent to participate was granted by each participant after reading out the prior informed consent information in compliance with the ethical requirements.

Consent to publish: Consent to publish the work was granted by the participants in compliance with the ethical requirements.

REFERENCES

Abrams, A.L., Carden, K., Teta, C., Wågsæther, K. 2021. Water, Sanitation, and Hygiene Vulnerability among Rural Areas and Small Towns in South Africa: Exploring the Role of Climate Change, Marginalization, and Inequality. *Water* 13(20), 2810. DOI: https://doi.org/https://doi.org/10.3390/w13202810

Boretti, A., Rosa, L. 2019. Reassessing the projections of the World Water Development Report. *npj Clean Water* 2, DOI: https://doi.org/10.1038/s41545-019-0039-9

Brazier, A. 2015. Climate Change in Zimbabwe: Facts for Planners and Decision Makers. pp. 1–188.

Chapungu, L. 2017. Impact of Climate Change on Vegetative Species Diversity in Masvingo Province, Zimbabwe. UNISA. Online available at http://hdl.handle.net/10500/23781

Chapungu, L. 2020(a). Mitigating the Impact of Cyclone Disasters: Lessons from Cyclone Idai. South African Inst. Int. Aff. Online available at https://policycommons.net/artifacts/1451486/mitigating-the-impact-of-cyclone-disasters/2083297/

Chapungu, L. 2020(b). Impacts of Climate Change on Falciparum Malaria Prevalence in Masvingo Urban, Zimbabwe, In Nyikahadzoi, K., Mukamuri, B.B. (eds): Building Climate Change Resilient Communites in Africa: Insights from Zimbabwe's urban and Rural areas. Konrad Adenauer Stiftung, Harare.

Chapungu, L., Nhamo, L. 2016. An assessment of the impact of climate change on plant species richness through an analysis of the Normalised Difference Water Index (NDWI) in Mutirikwi Sub-catchment, Zimbabwe. *South African J. Geomatics* 5(2), 244. DOI: https://doi.org/10.4314/sajg.v5i2.11

Chapungu, L., Nhamo, G. 2021. Interfacing vector-borne disease dynamics with climate change: Implications for the attainment of SDGs in Masvingo city, Zimbabwe. *Jamba J. Disaster Risk Stud.* 13(1), 1–12. DOI: https://doi.org/10.4102/jamba.v13i1.1175

Chapungu, L., Nhamo, L., Gatti, R.C., Chitakira, M. 2020. Quantifying changes in plant species diversity in a savanna ecosystem through observed and remotely sensed data. *Sustainability* 12(6), 2345. DOI: https://doi.org/10.3390/su12062345

Chazireni, E., Chigonda, T. 2018. The socio-economic impacts of dam construction: Case of Tokwe Mukosi in Masvingo province, Zimbabwe. *Eur. J. Soc. Sci. Stud.* 3(2), 209–218. DOI: https://doi.org/10.5281/zenodo.1410616

Conway, D., van Garderen, E.A., Deryng, D., Dorling, S., Krueger, T., Landman, W., Lankford, B., Lebek, K., Osborn, T., Ringler, C., Thurlow, J., Zhu T., Dalin, C. 2015. Climate and southern Africa's water-energy-food nexus. *Nat. Clim. Chang.* 5, 837–846. DOI: https://doi.org/10.1038/nclimate2735

Gulev, S.K., P.W. Thorne, J. Ahn, F.J. Dentener, C.M. Domingues, S. Gerland, D. Gong, D.S. Kaufman, H.C. Nnamchi, J. Quaas, J.A. Rivera, S. Sathyendranath, S.L. Smith, B. Trewin, K. von Schuckmann, and R.S. Vose, 2021: Changing State of the Climate System. In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change[Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 287–422, DOI: https://doi.org/10.1017/9781009157896.004

Hernandez R.R., Jordaan, S.M., Kaldunski B., Kumar, N. 2020. Aligning Climate Change and Sustainable Development Goals With an Innovation Systems Roadmap for Renewable Power. *Front. Sustain.* 1:583090. DOI: https://doi.org/10.3389/frsus.2020.583090

Iglesias, A., Garrote, L. 2015. Adaptation strategies for agricultural water management under climate change in Europe. *Agric. Water Manag.* 155, 113–124. DOI: https://doi.org/10.1016/j.agwat.2015.03.014

Ishtiaq, M. 2019. Book Review. Creswell, J. W. (2014). Research Design: Qualitative, Quantitative and Mixed Methods Approaches. (4th ed.). Thousand Oaks, CA: Sage. *English Lang. Teach.* 12(5), 40–41. DOI: https://doi.org/10.5539/elt.v12n5p40

Kalele, D.N., Ogara, W.O., Oludhe, C., Onono, J.O. 2021. Climate change impacts and relevance of smallholder farmers' response in arid and semi-arid lands in Kenya. *Sci. African* 12, e00814. DOI: https://doi.org/10.1016/j.sciaf.2021.e00814

Kanyepi, T., Tanyanyiwa, V.I. 2021. Urban Water Governance in Zimbabwe: Opportunities and Challenges Toward SDG6. 1–14. DOI: https://doi.org/10.1007/978-3-319-70061-8_182-1

Kivunja, C., Kuyini, A.B. 2017. Understanding and Applying Research Paradigms in Educational Contexts. *Int. J. High. Educ.* 6(5), 26. DOI: https://doi.org/10.5430/ijhe.v6n5p26

Kocsis, T., Kovács-Székely, I., Anda, A. 2020. Homogeneity tests and non-parametric analyses of tendencies in precipitation time series in Keszthely, Western Hungary. *Theor. Appl. Climatol.* 139, 849–859. DOI: https://doi.org/10.1007/s00704-019-03014-4

Loewenson, R. 2020. Extractives, climate and health equity trends in water resources in east and southern Africa. R Loewenson, Training and Research Support Centre in the Regional Network for Equity in Health in East and Southern Africa (EQUINET) 1.

Magesa, B.A., Mohan, G., Melts, I., Matsuda, H., Pu, J., Fukushi, K. 2023. Interactions between Farmers' Adaptation Strategies to Climate Change and Sustainable Development Goals in Tanzania, East Africa. *Sustainability* 15(6), 4911. DOI: https://doi.org/10.3390/su15064911

Mapetere, K. 2019. Water Demand Management Options in Masvingo City, Zimbabwe. *European Journal of Social Sciences Studies* 4(1), 45–56. DOI: https://doi.org/10.5281/zenodo.2545778

Mhiribidi, D., Nobert, J., Gumindoga, W., Rwasoka, D.T. 2018. Optimal water resource allocation modelling in the Lowveld of Zimbabwe. *Proc. Int. Assoc. Hydrol. Sci.* 378, 67–72. DOI: https://doi.org/10.5194/piahs-378-67-2018

Muchuru, S., Nhamo, G. 2019. A review of climate change adaptation measures in the African crop sector. *Climate and*

Development 11(10), 873–885. DOI: https://doi.org/10.1080/17565529.2019.1585319

Mujere, N. 2016. Sampling in Research. In: Baran, M.L., Jones, J.E. (eds.) Mixed Methods Research for Improved Scientific Study. IGI Global, USA. DOI: https://doi.org/10.4018/978-1-5225-0007-0

Mutimukuru-Maravanyika, T., Chapungu, L., Majeke, F. 2022. Food Systems in Dryland Communities: Challenges and Opportunities in Gutu District, Masvingo Province, Zimbabwe BT. In: Poshiwa, X., Ravindra Chary, G. (eds.): Climate Change Adaptations in Dryland Agriculture in Semi-Arid Areas. Springer Singapore, 157–172.

NASA, 2021. Mitigation and Adaptation | Solutions – Climate Change: Vital Signs of the Planet. Online available at https://climate.nasa.gov/solutions/adaptation-mitigation/

Ngoran, D.S., Etornam, D.W.Y.K., Xue, X. 2015. Assessing the Impacts of Climate Change on Water Resources: The Sub-Saharan Africa Perspective. Online available at http://www.nws.noaa.gov/os/brochures/climate/DroughtPublic2.pdf

Nhamo, G., Chikodzi, D. 2021. Floods in the Midst of Drought: Impact of Tropical Cyclone Idai on Water Security in South-Eastern Zimbabwe. In: Nhamo, G., Chikodzi, D. (eds): Cyclones in Southern Africa, Volume 1: Interfacing the Catastrophic Impact of Cyclone Idai with SDGs in Zimbabwe. Springer International publishing, Switzerland.

Pohlert, T. 2017. Non-Parametric Trend Tests and Change-Point Detection. Online available at https://cran.r-project.org/web/packages/trend/vignettes/trend.pdf

Rankoana, S.A. 2020. Climate change impacts on water resources in a rural community in Limpopo province, South Africa: A community-based adaptation to water insecurity. *Int. J. Clim. Chang. Strateg. Manag.* 12, 587–598. DOI: https://doi.org/10.1108/IJCCSM-04-2020-0033

Ricalde, I., Vicuña, S., Melo, O., Tomlinson, J.E., Harou, J.J., Characklis, G. 2022. Assessing tradeoffs in the design of climate change adaptation strategies for water utilities in Chile. *J. Environ. Manage.* 302, 114035. DOI: https://doi.org/10.1016/j.jenvman.2021.114035

Ritchie, H., Roser, M. 2017. Water Use and Stress. Our World Data. Online available at https://ourworldindata.org/water-use-stress

Scholes, R., Engelbrecht, F. 2021. Climate impacts in southern Africa during the 21 st Century. Online available at https://www.globalcarbonproject.org/carbonbudget/20

Siderius, C., Kolusu, S.R., Todd, M.C., Bhave, A., Dougill, A.J., Reason, C.J.C., Mkwambisi, D.D., Kashaigili, J.J., Pardoe, J., Harou, J.J., Vincent, K., Hart, N.C.G., James, R., Washington, R., Geressu, R.T., Conway, D. 2021. Climate variability affects water-energy-food infrastructure performance in East Africa. *One Earth* 4(3), 397–410. DOI: https://doi.org/10.1016/j.oneear.2021.02.009

Singh, C., Bazaz, A., Ley, D., Ford, J., Revi, A. 2020. Assessing the feasibility of climate change adaptation options in the water sector: Examples from rural and urban landscapes. *Water Secur.* 11, 100071, DOI: https://doi.org/10.1016/j.wasec.2020.100071

The Royal Society, 2020. Climate change Evidence and Causes. pp. 1–24.

UN-Water, 2019. Climate Change and Water UN-Water Policy Brief. The UN-Water Expert Gr. Water Clim. Chang. UN-Wate Policy Br., 28.

UNESCO, UN-Water, 2020. The United Nations World Water Development Report 2020: Water and Climate Change. Online available at https://unesdoc.unesco.org/ark:/48223/pf0000372985.locale=en

United Nations General Assembly, 2015. Transforming our world: The 2030 Agenda for Sustainable Development Transforming our world: The 2030 Agenda for Sustainable Development Preamble.

United Nations Water, 2021. Water and Climate Change. UN Water.

Weldegebriel, N.W., Gustavsson, H. 2017. Climate Change Adaptation and Mitigation Strategies Vis-À-Vis the Agriculture and Water Sectors in Ethiopia - Case Review/Study of the EPCC Project. *Environ. Pollut. Clim. Chang.* 01, DOI: https://doi.org/10.4172/2573-458x.1000125

Zhou, Y. 2013. Vulnerability and adaptation to climate change in North China : The water sector in Tianjin. Research Unit Sustainability and Global Change, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg, Germany.

ZINWA, 2002: Zimbabwe National Water Authority Act. Online available at http://www.zinwa.co.zw