Climate Resilience and Sustainability

WILEY

Climate Resilience and Sustainability
Interdisciplinary Approaches Towards Solutions for Climate Change
Open Access
RMetS

ORIGINAL ARTICLE OPEN ACCESS

Rural Farmer-Managed Wetland Agroecosystems Promote Climate Resilience in Semi-Arid Savannah: Case of Nyororo Wetland, Mberengwa District, Zimbabwe

Pascal Manyakaidze[1,2] | Regis Musavengane[2,3] | Robert Maponga[4]

[1]Department of Geography, Environmental Sustainability and Resilience Building, Faculty of Social Sciences, Midlands State University, Gweru, Zimbabwe | [2]Centre for Information, Learning and Knowledge Transfer, Local Initiatives and Development (LID) Agency, Shurugwi, Zimbabwe | [3]Department of Geography, Faculty of Natural and Agricultural Science, University of the Free State, Bloemfontein, South Africa | [4]Department of Geosciences, Faculty of Science and Engineering, Bindura University of Science Education, Bindura, Zimbabwe

Correspondence: Pascal Manyakaidze (pascalm83@gmail.com)

Received: 4 August 2024 | **Revised:** 12 March 2025 | **Accepted:** 27 March 2025

Funding: The authors received no specific funding for this work.

Keywords: agroecosystem | climate change | climate resilience | semi-arid areas | wetland ecosystem | Zimbabwe smallholder farmer

ABSTRACT

Climate change is threatening the resilience of smallholder agroecosystems in semi-arid areas. Wetland agroecosystems provide critical life support and positive outcomes for people, nature and climate in semi-arid areas. Wetland shrinkage, degradation, species extinction and habitat loss have threatened livelihoods and ecosystems across the globe. The study aimed to determine climate change impacts on farmer-managed wetland agroecosystems and evaluate resilience-building strategies in semi-arid rainfall marginal areas, focusing on Nyororo wetland in Mberengwa district. A mixed method approach informed data collection and analysis, influenced by interpretivism and objectivism research philosophical underpinnings. The mixed methods approach enabled the study to benefit from multiple knowledge domains, including professional ecological knowledge (PEK), scientific ecological knowledge (SEK), bureaucratic ecological knowledge (BEK), technological ecological knowledge (TEK) and local ecological knowledge (LEK). Information gathered through semi-structured questionnaires, interviews, focus group discussions, key informant interviews, secondary data, remote sensing and scientific measurements was synthesised to bring the resilience picture around wetland-based agroecosystems. The study findings on wetland degradation and climate change impacts on wetland agrobiodiversity included wetland shrinkage, an increase in invasive floral species by 25%, declining groundwater, reduced dryland cereal (*Zea mays*) production by 77.16% over a 41-year period, and the occurrence of crop pests and animal diseases, which had negative outcomes on wetland provisioning, regulatory services and ecosystem health. Resilience-building strategies, including adopting seasonal livelihood programmes, ecosystems-based adaptation (EbA) strategies such as wetland farming, protection of wetland water sources, harvesting wetland goods for selling and anticipatory action planning (AAP), including planting drought-tolerant, short-seasoned food crops, proved effective in the sustainable management of wetlands agroecosystems. The study recommended that financial mechanisms be tailored to suit the needs of local communities' conservation and resilient livelihoods. The study recommends that stakeholders swiftly implement the promising wetland agroecosystem resilience-building strategies that bring positive outcomes for people, nature and climate.

1 | Introduction

Globally, climate change impacts are felt across multiple sectors. This resulted in the world witnessing the unanimous signing of the Paris Agreement and later adoption of the Sustainable Development Goals, viewed as an organising concept for dealing with the climate challenge (Sachs 2015). Due to the weaker economy, the Global South recorded more impacts of climate hazards on society, the economy and the ecosystems (Ofori et al. 2021). The resilience of smallholder farmers to climate change is increasingly becoming a global issue. Increased climate change vulnerability for smallholder farmers in marginalised rural communities was noted to be on a rising trajectory due to the increasing recurrence of multiple shocks and hazards (Tol 2021). Despite being the producers of over two-thirds of global food (IFAD 2014), smallholder farmers' means of production continued facing climatic and economic shocks, among others. The declining rainfall and increasing temperatures, as noted by Brazier (2018), resulted in a heightened need for investments in irrigation infrastructure and climate-smart agriculture (FANPARN 2017). Globally, wetlands have supported the resilience of farming communities. In Zimbabwe, wetlands are defined as areas that are seasonally or permanently water saturated, and this covers 3% of the country's surface area (Zimbabwe Wetland Policy 2020). The area covered by wetlands was estimated to have declined by 35% across the globe since 1970, and over a quarter of the flora and fauna species are facing extinction (Gardner 2020). The pattern of wetland degradation was noted in Zimbabwe, with over 79% of wetlands having been altered and requiring urgent conservation efforts (Zimbabwe Wetland Policy 2020).

In the Zimbabwean context, rainfall variability continues to pose food crop production risk as the regions suitable for crop production continue to shrink (Mugandani et al. 2012; Mushore et al. 2021; Tol 2021). Among other communities, Mberengwa district falls within the Meteorological Region III (Meteorological Services Department 2018), which is associated with some of the greatest shocks and stressors (Zimbabwe Resilience Building Fund 2016). The drought risk for smallholder farmers was noted to be on the rise due to their low asset base and poor coping mechanisms (Frischen et al. 2020). The overdependency on subsistence rainfed agriculture resulted in the deterioration of smallholder farmers' livelihoods. Increasing difficulties in managing key livelihood resources, including water (Behnassi et al. 2018) and wetlands (Chikodzi and Mufori 2018), were noted to be related to changing and highly variable climatic impacts. Rainfall patterns have chiefly become more unpredictable and unreliable, leading to increased surface and groundwater decline (Manyakaidze et al. 2024).

Climate change impacts continue to infiltrate the socio-economic context of the country (Chanza and Gundu-Jakarasi 2020). Zimbabwe and Africa, to a larger extent, continued bearing the burden of coping with drought risk as droughts are becoming more frequent and intense, undermining social and economic progress, including power generation, poverty reduction (Filho et al. 2023; Masih et al. 2014; Quandt 2021) and the Gross Domestic Product [GDP] (Filho et al. 2023; Masih et al. 2014; Quandt 2021). Attri et al. (2017) revealed that climate change and other shocks drive food insecurity to the riskiest levels, making recovery more challenging. According to the Zimbabwe Resilience Building Fund (2017), climate change-induced El Niño has accounted for over 65% of droughts in Zimbabwe since 1963. Some of the worst droughts and biggest humanitarian appeals recorded in Zimbabwe's history were during the El Niño period, which increased crop failure cases (Government of Zimbabwe 2024; UNOCHA 2019). Zimbabwe's droughts account for the heightened food deficit that resulted in the food-insecure population increasing from 2.7 to 7.2 million in 2022/2023 and 2023/2024 consumption years, respectively (Government of Zimbabwe 2024). The context increased the proportion of aid-dependent communities and individuals (Mushore et al. 2021).

Over the years, Zimbabwe's drought-prone communities have depended on wetland goods and services for their livelihoods. Due to overutilisation, wetlands continued to degrade due to increased socio-economic pressure from the growing population threatened by climate change impacts (Makarati et al. 2021). The value of wetland goods and services continues to follow a declining pattern due to the impacts of climate change (Marambanyika et al. 2021). The farmer-managed wetlands-based agroecosystems approach is increasingly becoming more important in influencing a balance between wetlands conservation and human livelihoods in semi-arid communities of Zimbabwe. With only 3% of Zimbabwe's surface area being covered by wetlands, only 21% of these wetlands are regarded as in good conservation status, whereas the rest (79%) have been altered and degraded to varying degrees (Zimbabwe Wetland Policy 2020). The lack of resilience-building strategies at the local level to harmonise wetland biodiversity conservation, policy implementation and farmer-managed agroecosystems presents a gap in the management and conservation of wetland ecosystems. The study's objectives were (i) to assess climate change impacts on farmer-managed wetland agroecosystems in semi-arid areas and (ii) to determine resilience-building strategies for smallholder farmers dependent on wetland agroecosystems in semi-arid rural areas. Grounded within a resilience-building theoretical framework, which posits that absorptive and adaptive capacities provide the first and second layers in supporting community resilience against shocks, the study hypothesised that differences in seasonal rainfall performance influence wetland cropping patterns in drylands. The research targeted smallholder farmers from Nyororo wetland in Mberengwa district, which is within the semi-arid agro-ecological zone V. It was significant for the study to identify and document climate change–related and variability-related impacts on wetlands and recommend resilience-building strategies for integrating climate change adaptation, mitigation and community development.

2 | Resilience-Building Theory

The resilience-building strategy influenced the research (Green Climate Fund 2022; UNDP 2015), which defines the community's capacity to bounce back better after experiencing shocks and disturbances. The resilience-building strategy promotes anticipatory action thinking (Anticipation Hub 2022; OCHA 2024), which advocates for 'proactive risk management' of a system (World Food Programme 2022a). With climate change and variability affecting ecosystems and community livelihoods, Mberengwa district is highly prone to climate change impacts. Being located in a rainfall marginal agroecological region V

(Manatsa et al. 2020), the Nyororo community in Mberengwa district is threatened by drought, crop pests and animal disease hazards (Zimbabwe Resilience Building Fund 2016). Smallholder farmers who depend on ecosystems, including wetlands, dominate these communities. The livelihood coping strategies are influenced by rainfall performance (Frischen et al. 2020; Welt Hunger Hilfe and Government of Zimbabwe 2021; World Food Programme 2022a), changes in market prices of basic commodities (World Food Programme 2021, 2022b) and other economic activities in the areas, including artisanal mining. In this view, the study evaluated resilient building strategies for farmer-managed wetland agroecosystems for the Nyororo community within the Mberengwa district of Zimbabwe. The focus was to determine the contribution of wetland agroecosystems to the three community resilience capacities: absorptive, adaptive and transformative, as enabled by wetland agroecosystems. Absorptive capacity focuses on the contribution of wetland agroecosystems in building coping strategies that reduce community exposure to climate shocks, whereas adaptive and transformative capacities focus on system adjustment in response to climate change impacts and the systems change as an enabler for climate change impacts management, respectively (UNDP 2015).

3 | Materials and Methods

3.1 | Description of the Study Area

The research was conducted in the Mberengwa Rural District Council (MRDC) jurisdiction areas, Ward 30, Nyororo wetlands (Figure 1). The area falls under agroecological zone (AEZ) V, which receives low, erratic rainfall averaging between 400 and 550 mm per year (Manatsa et al. 2020). Of the total (4976) ward population, 45% were male, and 55% were female (ZIMSTAT 2022). Food insecurity is a challenge in the ward, with the population reaching 52% having been reported to be cereal insecure and 93% affected by droughts (ZIMLAC 2024). Over 70% of the 1090 households (ZIMSTAT 2022) depend on wetland utilisation for crop production as a coping mechanism against recurrent drought. Mberengwa district falls under the livelihoods zone known as the Mwenezi–Chivi and South Midlands Communal (ZIMVAC 2010). The livelihood zone covers Mberengwa, Mwenezi and some parts of the Zvishavane and Chivi districts. The community depends on crop production, livestock rearing, casual labour and cross-border trading. In recent years, mining activities have supported the communities through gold panning, chrome and lithium mining (ZIMVAC 2022). Key shocks and hazards affecting the areas include soil erosion, droughts (Defe and Matsa 2021), crop pests (Zimbabwe Resilience Building Fund 2016), animal diseases and fluctuating cereal prices (Dube 2018).

3.2 | Research Approach

The study adopted a mixed methods design (Onwuegbuzie and Collins 2007), in which the qualitative approach was more dominant than the quantitative, as influenced by the interpretivism philosophy. Objectivism philosophy (Biddle 2021) helped the study deal with data from statistical and scientific domains. Objectivism relies on scientific measurements (Biddle 2021) that are key in providing evidence of climate and ecosystem change as required by the study to triangulate data from various sources in answering research objectives. Using qualitative and quantitative methods enabled in-depth analysis of the community's lived experience and related community insights with data from scientific and statistical domains.

3.3 | Data Collection

The study depended mainly on primary data to generate empirical evidence, which Ajayi (2017) described as the original research data collected by the researcher solely for the study. Secondary data generated by other entities for their primary use was used in the research due to the relevance of the data in providing insights and answering research objectives (Johnston 2017). Secondary data in this study were population and demographics gathered from ZIMSTAT (2022), cereal (*Zea mays*) production records from AGRITEX and climate information from the Meteorological Services Department for the 1980 to 2020 period, ward-level community adaptation action plans from MRDC and the Zimbabwe Livelihoods Assessment Committee (ZIMLAC 2024) food security reports. Secondary data for the stated period were key in backing empirical evidence generated by primary data sources and ensuring research findings were grounded within the study context (Johnston 2017; Kabir 2016).

3.3.1 | Qualitative Data Collection

3.3.1.1 Semi-Structured Household Questionnaire Interviews. A semi-structured household questionnaire (Supporting Information Annex 1) was used to collect data from wetland user household representatives through interviews. The questionnaire was designed to provide opportunities for probing further for emerging information and insights. The selection of household research participants followed a random sampling procedure for enrolling a representative sample of the general study population (Adhikari 2021). Sampling was conducted to ensure that the empirical study results can be correctly inferred from the population under study (Bujang and Adnan 2016). A study of this nature that targeted larger groups such as Nyororo smallholder farming households who are 1090 required the deployment of Cochran's standard sampling equation (Charan et al. 2021; Cochran 1963). The Cochran formula can be applied to different population sizes. For smaller groups, it takes a conservative measure by increasing the proportion of respondents from the population to ensure the generalisability of the results. The targeted group is affected by the global climate change phenomena; hence, a standard sampling technique was required for the results to be more representative. Cochran's standard sampling formula, as suggested by Adhikari (2021), was used as follows:

$$n_0 = \frac{Z^2 p\, q}{e^2}$$

where n_0 is the sample size; Z is the confidence level (95% acceptable in social science = 1.96); p is the prevalence/proportion of the population with desired characteristics (78% = 0.78); q is the $1 - p$; e is the desired level of precision or acceptable margin of error (5% = 0.05).

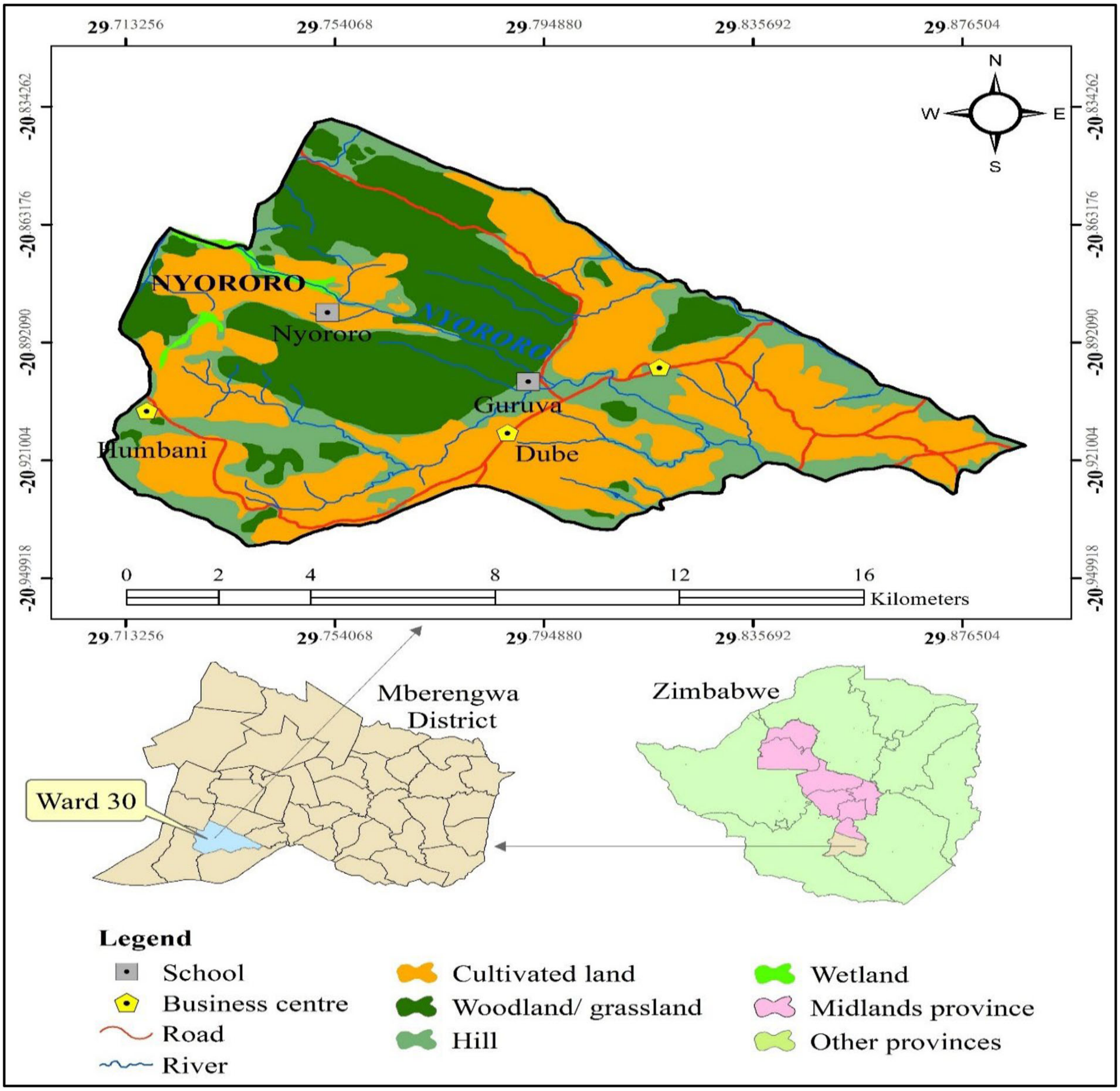

FIGURE 1 | Location of Nyororo Wetland study site. *Source:* Author (2024).

Therefore,

$$n_0 = \frac{1.96^2 \times 0.92 \times (1 - 0.92)}{0.05^2 = 3.8416 \times 0.92 \times 0.08/0.0025 = 113.1}.$$

The study, therefore, enrolled 113 Nyororo wetland user smallholder farmers for the semi-structured questionnaire survey.

The research took advantage of Cochran's formula, which allowed for conservative measures by assuming a larger proportion of the population (79%) to achieve a more representative sample size, the results of which are highly acceptable when generalised. The stages for identifying these farmers included the generation of a farmer register using village registers for wetland users. The Nyororo farmers' list was generated only for those who agreed to participate in the study, which aligns with the need to uphold and respect prior informed consent (FAO 2014). The full farmer register for Nyororo wetland users was used to select 113 participants using random sampling that allowed every farmer to participate in the survey. All the registered farmers were coded using the 'NWF' code for Nyororo Wetland Farmer and a unique number ranging from 01 to 142. The selected farmers were approached, allocated codes and interviewed. One key advantage of a semi-structured interview is that it allows for the collection of vast data covering multiple questions (Kielmann et al. 2012). It also allows for confidentiality and privacy of information. The collected data focused on the resilience of smallholder farmers by assessing their reliance on wetlands and drylands for food production. The questionnaire survey included questions about historic climate impacts, shocks, stressors and coping mechanisms.

Focus Group Discussions (FGDs). Purposive sampling was deployed to target participants of focus groups who were knowledgeable about the subject, as stressed by Lapan et al. (2012). Three FGDs were conducted, each comprising seven to nine

TABLE 1 | Selection of focus group discussion participants.

Research participant	Number	The approach used to contact the participants	Justification for participation
Women wetland users	9	These FGD participants were enrolled from respondents of the semi-structured questionnaire survey. Their selection enabled the triangulation of questionnaire findings	Women constituted 55% of the population, and the study targeted them to gain insights into climate change and agroecosystem resilience
Nyororo wetlands user committee	7	A meeting was held with the village head and ward Councillor to select the voluntary participants	Wetland committees participated in focus group discussions since they knew about the key wetland activities implemented by farmers
Mixed age and sex group of farmers	9	Three female and male wetland user farmers between 36 and 70 years old and 3 youths 35 years of age and below were selected from semi-structured questionnaire respondents	A mixed group of participants in the FGD was considered key to creating a balanced discussion that generated consensus among community wetland users

Source: Author (2024).

smallholder farmer representatives (Mishra 2016). One group comprised women farmers only, the second group comprised local leadership representatives and the third was a mixed group of youth, women and men smallholder farmers. The participants of the focus group discussion were drawn from participants of the semi-structured questionnaire survey to ensure triangulation of the findings through consensus building and verification of emerging issues. Targeting different community groups ensured that the information generated was representative of all required demographic structures. Purposive sampling enabled the research to target the members of the communities that were directly involved in the daily management of wetlands and those who held influential official decision-making roles, as Innes and Connick (2001) recommended. The researcher guided the discussion by facilitating discussion topics, probing wherever possible and recording the findings. A set of open-ended predetermined questions (Supporting Information Annex 2) were asked to stimulate discussions around the study's objectives, including climate change impacts on wetland agroecosystems and resilience-building strategies for wetland agroecosystems. The researcher guided group discussions and probed further to gather detailed information. Comprising people with diversified experiences and views, the study took advantage of the discussions that generated different views and opinions around rural farmer-managed wetland agroecosystems and resilience. Table 1 presents the focus group discussion participants selected and justification.

Key Informant Interviews (KIIs). Purposive sampling was deployed to target eight key informants who were knowledgeable about the subject, as stressed by Lapan et al. (2012). Representatives of traditional leaders, wetlands user committees, local authorities, community-based organisations (CBOs) and extension services providers were selected for the KIIs (Supporting Information Annex 3), as detailed in Table 2.

Field Observations. Field observations were used to collect firsthand data on the physical status of wetlands, climate change impacts and adaptation strategies. A checklist was used to identify the key observable changes in wetlands. This helped triangulate the narratives of FGDs and KIIs. The checklist was developed using the variables and themes that emerged during FGDs and KIIs. Community leaders led the researchers in the identification and observation of changes in the size of wetlands, areas under crop production and wetland water sources.

3.3.2 | Quantitative Data Collection

Remote Sensing of Wetland Extent. The study used remote sensing to assess the changes in the size of the area covered by the Nyororo wetland over time, as influenced by climate change. The United States Geological Survey (USGS) Earth Explorer enabled the researcher to download images for the years 1990, 2000, 2011 and 2021 during the driest period (September and October). The selection of specific years that signified the normal decadal climatic conditions allowed the study to solve data distortions from seasonal variations and key climatic events affecting the normalised difference moisture indices (NDMI) analysis. Such events with great potential for distorting data include the significant drought and flooding seasons recorded in 1981–1983, 1992, 2007, 2008, 2015, 2016 and 2019. Information about the type of data used is presented in Table 3.

Remotely sensed data acquisition and preprocessing were done by delineating the study area boundary using the Arc-GIS 10.5 shapefiles. The researchers downloaded satellite images from USGS Earth Explorer for 1990, 2000, 2011 and 2021 from https://earthexplorer.usgs.gov. The downloaded shapefile was reprojected from World Geodetic System (WGS) 1984) to UTM Arc 1950 zone 36S. Scene referencing for Landsat Satellite imagery was determined by overlaying the shapefile with the Landsat scene reference shapefile. The images were pre-processed through layer stacking (stacked three bands) for Landsat 5 (Bands 5, 4, 3) and Landsat 8 (Bands 4, 3, 2). The georectification process of downloaded images was done. Therefore, images in WGS84 36N were geo-rectified to Arc 195 UTM 36S for all the years. Due to the reflective nature of the 1990 images, radiometric correction was done through the assignment of known reflectance to physical objects because the 1990 images were not already calibrated when downloaded. However, Landsat 8 was already corrected. Masking

TABLE 2 | Selection of key informant interview participants.

Research participant	Number	The approach used to contact the participants	Justification for participation
Extension service providers	2	A request was directed to district offices for government extension officers to participate. An information session provided information to officers who agreed to participate voluntarily	The selection was based on the key roles of extension officers, who are technical and responsible for training and knowledge transfer to smallholder farmers whose livelihoods depend on Nyororo wetland agroecosystems
Local authorities	1	A letter was sent to the Chief Executive Officer (CEO) of MRDC, who granted permission to interview the Environmental Officer. The officer agreed to participate in the interview	Local authority officials were targeted due to their critical role in conserving the environment within their jurisdiction. They provided insights about community resilience and the local environmental action plans
Traditional leaders	4	Appointments were made for the visit, and the traditional leaders proposed a date for all village heads who depend on the Nyororo wetland to convene at a central point for the information session. In consultation with the research team, a new interview date was set	Traditional leaders are the community and local environment custodians defined by the Traditional Leaders Act (Government of Zimbabwe 1998). They provided key local, traditional and Indigenous knowledge and insights about the wetlands and their conservation
Community-based organisations (CBOs)	1	The MRDC provided contacts for officers from a local CBO operating in the area. Appointments and information sessions were held over the phone. A key informant interview was conducted at the Nyororo micro-irrigation project	The study interviewed the CBO representative for their involvement in financing wetlands conservation projects, social enterprises, borehole water development and irrigation development

Abbreviation: MRDC, Mberengwa Rural District Council.
Source: Author (2024).

TABLE 3 | Type of data used.

Year	Landsat sensor type	Scene reference		Date image was captured	Source	Spatial reference of image on downloading
		Path	Row			
1990	Landsat 5 Level 1	170	073	29/10/1990	USGS Earth Explorer (https://earthexplorer.usgs.gov/)	WGS_1984_UTM_Zone_36N
2000	Landsat 5 Level 1	170	073	20/09/2000		WGS_1984_UTM_Zone_36N
2011	Landsat 5 Level 1	170	073	27/08/2011		WGS_1984_UTM_Zone_36N
2021	Landsat 8 Level 2	170	073	31/10/2021		WGS_1984_UTM_Zone_36N

Abbreviation: USGS, United States Geological Survey.

was done to cut out the study area from the overall map for the 4 satellite images. The digitised training samples for each land cover type guided imagery processing for the selected years. The NDMI index was calculated to determine areas covered by moisture, and the NDMI values were presented in graphical form (Figure 3).

Secondary Data. Secondary data that were generated by other parties for their use were used in the research due to the data's relevance in answering research objectives (Johnston 2017). The study collected historical rainfall data from the Meteorological Services Department for 40 years (1980–2020). Rainfall data were collected because rainfall plays a key role in shaping agroecosystems, livelihoods and the resilience of targeted research communities. Cereal (*Z. mays*) production data from 1980 to 2020 was gathered from individual farmers' records and further triangulated with local Agricultural Extension Services (AGRITEX) officers' records. The research generated trends in the performance of rainfed and wetland cereal production in response to seasonal rainfall patterns.

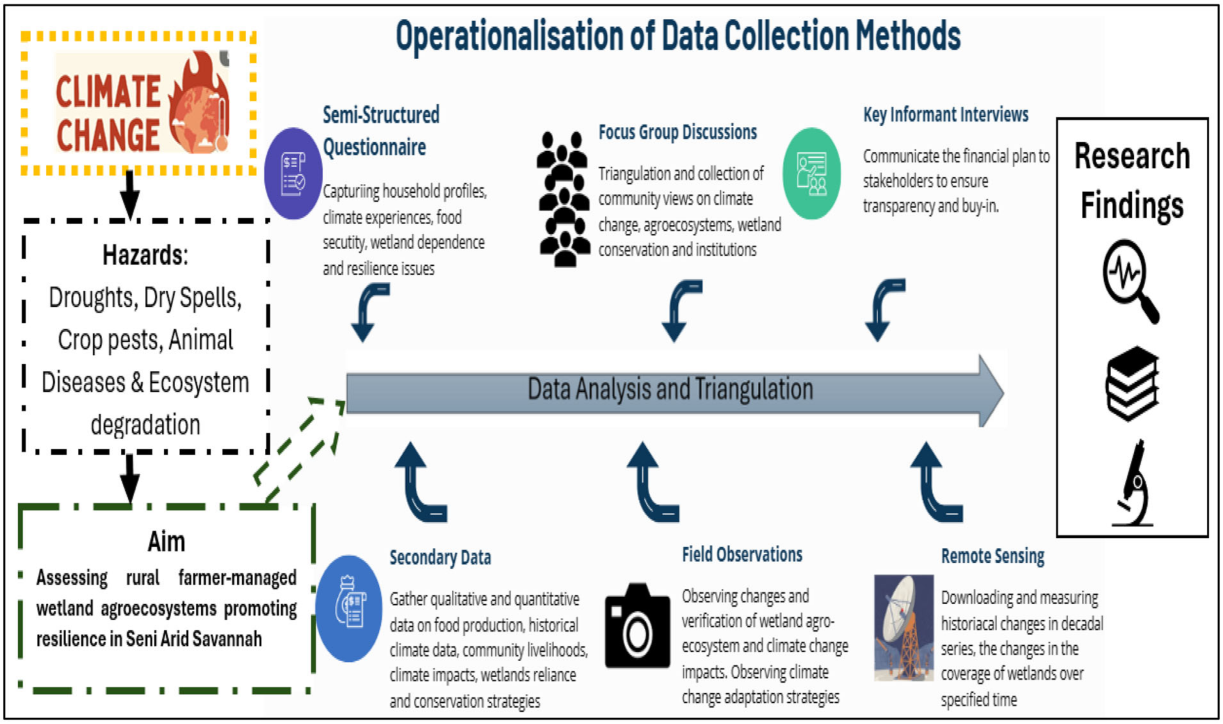

FIGURE 2 | Overview of the methods. *Source:* Author (2024).

An overview of the different methods is presented in Figure 2.

3.4 | Data Analysis

Quantitative and qualitative data analysis techniques were utilised in line with the mixed method nature of the study. Statistical data analysis packages, including Statistical Package for Social Sciences (SPSS) (Arkkelin 2014), R (R Core Team 2024) and online DATAtab.net (DATAtab Team 2024), were used to analyse quantitative data. Descriptive statistics, multivariate analysis of variance (MANOVA), Pearson's correlation, pairwise scatter plots and Bonferroni post hoc test outputs were produced and interpreted to define the statistical significance of the study findings around seasonal rainfall influence on wetland and dryland crop cultivation and yields. The study's hypotheses are as follows:

Null hypothesis (H_O). There is no correlation between seasonal rainfall influence on area under dryland and wetland cropping.

Alternative hypothesis (H_1). *There is a correlation between seasonal rainfall influence on area under dryland and wetland cropping.*

Rainfall influence and priorities for wetland use in different seasons as climate change adaptation strategies were identified. The interaction of factors was also determined through post hoc tests.

Qualitative data was analysed using content analysis, identifying patterns, emerging themes and meaningful insights from the collected data sets. Data gathered from KIIs and FGDs with Nyororo wetland users provided insights into climate change impacts and wetland agroecosystem resilience issues. Due to the varied experiences of the farmer groups interviewed, content analysis enabled the harmonisation of oral history and interpreted human memories into readable, meaningful insights generated through discussions (Babbie 2011; Haradhan 2018).

The analysis of remotely sensed images employed supervised image classification to ensure high accuracy in analysing Nyororo wetland images. Using the created signature file, the study classified the images using the maximum-likelihood classification, which used the generated spectral signatures and other site features identified in the training sites. The NDMIs were calculated over time for the period under assessment for the Nyororo wetland. This determined changes in the extent of wetland as depicted by the area covered by moisture during the driest period of the year.

4 | Results and Discussion

4.1 | Climate-Related Impacts on Wetland Agroecosystems

4.1.1 | Climate Change Impacts on Food Production

Participatory data collection techniques (questionnaire, focus group discussion and KIIs) revealed drought as a top-ranked climate-related challenge affecting Nyororo wetland agroecosystems. Extension service providers and smallholder farmer group committees indicated the area's drought proneness, as over 66% of seasons had received below-normal rainfall for the assessed period, 1980–2020. Late seasonal rainfall onset, mid-season dry spell and early rainfall cessation reportedly resulted in reduced

TABLE 4 | Dryland and wetland cereal production under different rainfall seasons.

	N	Mean	Std. Deviation
Annual rainfall (mm)	40	482.94	186.79
Dryland yields (kg)	40	866.25	668.38
Wetland yields (kg)	40	892.6	198.41

crop planting time for smallholders, affecting plant health due to moisture stress, plant wilting and cereal deficit that affected even traditional grains, including sorghum, pearl and finger millet, which are known for being drought tolerant. It was significant for the study to reveal the increased occurrence of drought-related multiple hazards that affected farmers within a single cropping season.

The findings revealed an increasing trend in the influence of droughts on cropping and livelihoods for the 40 years covering 1980–2020 (Table 4). It was noted that the area's average annual rainfall of 482.94 mm was far below the national average of around 670 mm (The World Bank Group 2020, 2021; ZIMSTAT 2016). The area's rainfall deviated greatly from the mean by 186.79 mm, as testified by smallholder farmers' cases that revealed the unpredictability of seasonal rainfall and the inadequacy of rainfall for cropping cultivation, domestic and livestock requirements. To further confirm the claims that climate-induced droughts, mid-season dry spells, late-onset and early cessation are affecting cereal crop production, the descriptive statistics indicated that crop yields in the drylands were deviating from the mean with a higher margin than crop yields in wetlands. The standard deviation for dryland yields was 668.38 kg from the mean of 866.25 kg, compared to the smaller deviation of 198.41 kg of wetland yields against its mean of 892.6 kg (Table 4). Furthermore, smallholder farmers' records indicated that farmers yield more cereals in wetlands than drylands due to the wetlands' inherent soil moisture that promotes plant growth in semi-arid areas.

Crop production was further reported to have been undermined by reduced land utilisation in drylands due to unfavourable drought conditions. Farmers reported that they only put a small portion under crop production in drylands when they receive below-normal rainfall. It was further reported that more land was put under crop cultivation when the seasonal rainfall performance was forecasted to be normal to above normal. The study used Pearson's correlation to assess the farmers' claims on the relationship between the arable areas under crop cultivation in wetlands and drylands and the seasonal rainfall performances, as presented in Table 5 and Figure 4.

The study analysed the following pairs and produced the following results:

i. Wetland cropping area (ha) vs. dryland cropping area (ha), (p value = 0.015)

There is a moderate inverse relationship between dryland and wetland areas under cropping, as confirmed by the correlation of −0.66. An inverse relationship was observed between wetland and dryland areas under cropping. The p value = 0.015 is less than 0.05; therefore, we reject Ho and conclude that there is a statistically significant relationship between the pair.

i. Rainfall (mm) vs. dryland cropping area (ha), (p value = 0.09)

A weak negative correlation exists among dryland hectares, crop cultivation each year and rainfall (mm) (r = 0.49; p = 0.09). Therefore, we fail to reject Ho and conclude that there is no statistically significant correlation between the pairs. This indicates that farmers' assumption that the area under dryland crop cultivation over 40 years was declining is not statistically significant.

i. Rainfall (mm) vs. wetland cropping area (ha), (p value = 0.344)

The pair's correlation (−0.29) indicates a weak relationship. The p value of 0.344 for wetland hectares (ha) under crop cultivation each year and rainfall (mm) is greater than 0.05. Therefore, we fail to reject Ho and conclude that there is no statistically significant correlation between the pair. This indicates that farmers' assumption that the area under wetland crop cultivation was increasing is not statistically significant. The assessed drought scenarios were linked to Zimbabwe's largest humanitarian crisis that attracted the country's largest global appeals in line with the country's declaration of the drought condition as a state of emergency that attracted international appeals for support (Government of Zimbabwe 2016, 2024).

Increased Cases of Crop Pests and Animal Diseases. The key informants and focus group discussion participants indicated climate change heightened crop pest and animal disease incidence. One farmer highlighted that *Spodoptera frugiperda* (fall armyworms) were first noticed during the 2015/2026 El Niño-induced drought. Today, the fall armyworm is considered a serious tropical migratory pest that is spreading across the globe (Kansiime et al. 2019). Farmers reported that using chemicals proved effective in controlling fall armyworm, despite the health and ecological threats and disruptions associated with chemicals. When asked about the application and effectiveness of the push–pull system that depends on ecological processes (Bay 2020; Guera et al. 2021), farmers indicated that the pest inhibits temporal and spatial responses due to climate change and variability factors that alter seasonal temperature and rainfall performance. *Theileriosis* (January Disease) outbreak also caused serious damage to smallholder farmers whose livelihoods depended on crop and livestock integration. Over 95% of participants in the questionnaire survey agreed that *theileriosis* was first reported in the community in 2018, and 60% of these respondents revealed that they lost over 45% of their cattle due to the disease. The officials who responded to the KIIs concurred with smallholder farmers and indicated an overall reduction of 30% in the livestock population due to theileriosis. Crop pests and animal diseases were globally confirmed to be following the climate change patterns, with high temperatures and low rainfall increasing livestock susceptibility to the disease (FAO 2018; Oluwagbemi et al. 2022).

TABLE 5 | Pearson's correlation analysis: dryland and wetland cereal production for different seasons.

Correlation matrix and significance				
		Annual rainfall (mm)	Dryland cropping area (ha)	Wetlands cropping area (ha)
Annual rainfall (mm)	Correlation	1	0.49	−0.29
	p		0.09	0.344
Dryland cropping area (ha)	Correlation	0.49	1	−0.66
	p	0.09		0.015
Wetlands cropping area (ha)	Correlation	−0.29	−0.66	1
	p	0.344	0.015	

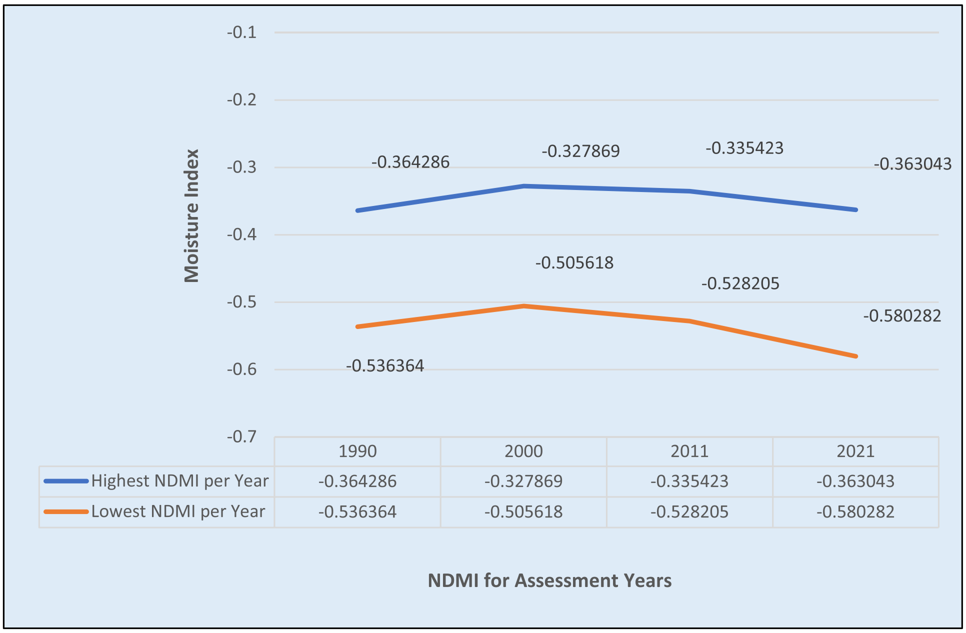

FIGURE 3 | Nyororo normalised difference moisture indices (1990–2021). *Source:* Author (2024).

4.1.2 | Climate Change Impacts on Wetland Extent

Smallholder farmers noted a rapid shrinkage of the Nyororo wetland over the past three decades. During field observations, the researcher identified dry wooden tree poles previously used to fence the gardens. These wooden poles were located 120 m in the dry land, far from where wetland features and plant indicator species are. This was explained as the indicator for the shrinking wetland. To assess the extent of shrinkage, the study used remote sensing techniques, the USGS Earth Explorer, to identify the changes in wetland size as depicted by the vigour of the wetland vegetation species through the NDMI. The NDMI is a key tool in monitoring soil moisture through water stress detection in vegetation. For wetland shrinkages, soil moisture detection through vegetation vigour in the driest season provided a good measure of detecting wetland coverage. The NDMI enabled the study to detect temporal wetland areas through plant vigour driven by soil moisture availability or stress. The NDMI was calculated from the 1990, 2000, 2011 and 2021 remotely sensed images (Figure 3).

A slight increase in the wetland area was identified between 1990 and 2000. Between 2000 and 2021, the results confirmed a decline in the surface area covered by wetlands (Figure 3). The NDMI ranges remained between −6 (lowest) and −3 (highest), representing vegetation with low canopy cover during wet or dry seasons, like the grasslands that dominate the vegetation cover of the study site. When probed for an explanation, the participants of KIIs and FGDs highlighted that the identified situation conformed to the high temperatures, low rainfall and increased wetland cultivation that had influenced the decline in wetland areas. Other remote sensing studies alluded that climate change impacts in Zimbabwe resulted in wetland shrinkage, as confirmed by Bhaga et al. (2020). The observed shrinkage of the Nyororo wetland was associated with declining groundwater levels of perennial wells, as Manyakaidze et al. (2024) supported.

4.1.3 | Climate Change Impacts on Biodiversity and Ecosystem Services

The study identified the declining water quality and biological diversity as a challenge that undermined the resilience of smallholder farmers. Through field observations, the study noted the encroachment of invasive alien species due to the increasing aridity of some sections of the wetland. Over 11% (nine species) of all the assessed herbaceous wetland species were identified to be of alien origin, with 25% of these alien species being invasive or noxious by nature. Key wetland provisioning services, including water for domestic and livestock, food and non-timber wetland goods, have declined by 27% over the past three decades. Findings by other scholars confirmed the negative influence of climate change on wetland utilisation, including their shrinkage and fragmentation (Musasa and Marambanyika 2021; Nyamadzawo et al. 2015) and ecosystem degradation (Adeeyo et al. 2022; Fakarayi et al. 2015). Mwenge et al. (2021) stressed that key biological diversity hotspots are threatened by climate change, resulting in increased land use and cover changes within wetlands. In Zimbabwe, the study was supported by the Zimbabwe Wetland Policy (2020) on the devastating impacts of the El Niño phenomenon, which occurs more frequently and accounts for 62% of the recorded below-normal rainfall.

4.2 | Resilience-Building Strategies for Wetland Agroecosystems

After identifying the impacts of climate change on Nyororo wetland agroecosystems, the study determined wetland ecosystem-based resilience-building strategies that help farmers develop absorptive, adaptive and transformative capacities to counter climate change impacts (Green Climate Fund 2022). The study was key in identifying and evaluating sustainable strategies implemented by smallholder farmers utilising Nyororo wetland while safeguarding the ecosystems from maladaptation. Building the community's Anticipatory Action Plans (AAP), using ecosystem-based adaptation (EbA) and Seasonal Livelihoods Planning (SLP), were ranked as high-promising strategies for achieving a climate-compatible agroecosystem.

4.2.1 | AAP Approach

The KIIs and focus group discussion participants indicated they gained key lessons over time as climate change influenced seasonal rainfall performances and temperature regimes. The use of climate information in planning food crop production by smallholder farmers was identified as a key area enabling wetland users to determine land preparation, inputs, type of crops and the timing for planting. It was noted that smallholder farmers anticipate a good harvest when the seasonal rainfall forecast is normal to above normal (Meteorological Services Department 2020). During a bad season with a forecast of below normal rainfall, the farmers resort to destocking livestock and planting traditional grains that perform better with little rainfall. The study noted that seasonal rainfall performance influenced crop production patterns in dry and wetlands (Figure 4).

The research further confirmed the smallholder farmers' claim by assessing the statistical significance of the noted changes using the MANOVA (Table 6). The following hypotheses provide the claim:

$$\mathrm{H}_0\colon \mu_1 = \mu_2 = \mu_3$$
$$\mathrm{H}_1\colon \mu_1 \neq \mu_2 \neq \mu_3$$

P—Values. Results of the MANOVA indicate that all 4 tests (Pillai, Wilks, H-Lawley and Roy) have p value = 0.0003867, which is less than 0.05. Therefore, the study rejects H_0 and concludes that there is a significant difference in the treatment effects (inherent soil moisture to crop yields harvested from wetlands and drylands).

Effect Size (η^2 - Eta Squared). The eta squared (η^2) value is 0.25 (25%), representing the proportion of the variance in the dependent variables that are attributable to the soil moisture conditions (dryland and wetland). In this context, 25% of the variance in the dependent variables can be explained by the differences between the soil moisture levels between wetlands and drylands. The eta squared value (η^2) of 0.25 suggests a large effect size. This translated into a 25% difference in yield due to the inherent moisture in wetlands compared to drylands. According to Cohen (1988), the statistical power represented by the limits for the effect size Eta-Quadrat is 0.01 (small effect), 0.06 (medium effect) and 0.14 (large effect). The results indicate a much higher production level, as represented by eta squared (η^2) 0.25, depicting the critical value of provisioning services wetlands offer for communities in an anticipation mode for the drought effects.

Bonferroni Post Hoc Test. Due to statistically significant differences in the effects of soil moisture in wetlands and drylands under different seasonal rainfall performances, the Bonferroni post hoc test (Table 7) was used to identify the pairs with the most significant differences.

The results of dryland yields (kg) versus wetland yields (kg) under the same rainfall resulted in a p value = 0.0033, which confirms a significant difference in crop yields influenced by inherent soil moisture. Smallholder farmers, therefore, increased wetland crop production under changing climatic conditions to avert the effects of drought on food production. This aspect of AAP builds the resilience of wetland-based agroecosystems.

4.2.2 | Ecosystem-Based Adaptation

During the field observations and FGD, the participants indicated that wetland goods and services supported household resilience against climate change–related shocks and hazards. Access to food, water, pastures and fibre supported communities' daily livelihoods and provided a coping mechanism for recurring climate-induced droughts. This finding concurs with studies on goods and services from the Driefontein wetlands by Musasa and Marambanyika (2021). EbA was noted to be a resilient way of sustaining the climate–water–food nexus. The challenge indicated included the continued shrinking of the wetland

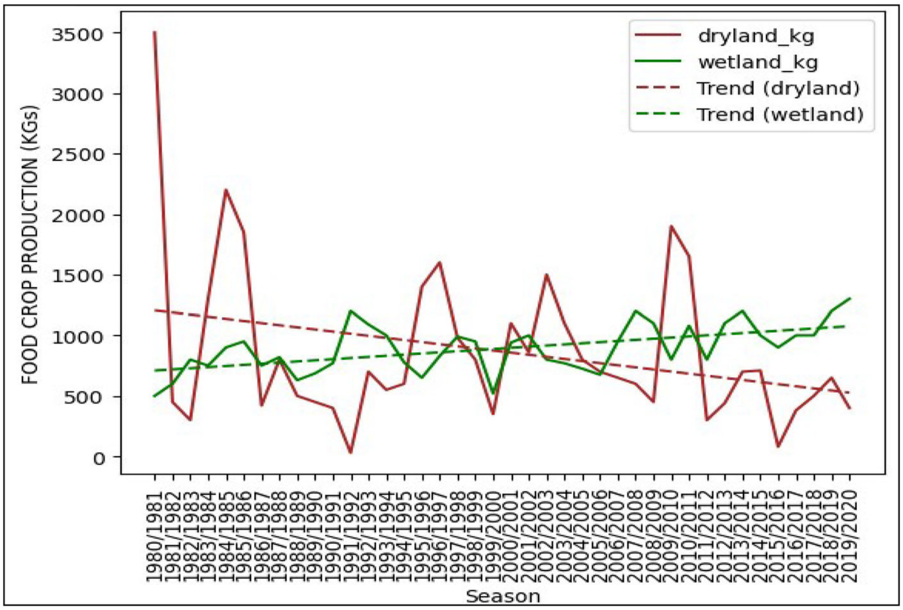

FIGURE 4 | Trends in cereal crop production between wetlands and drylands (1980–2020). *Source:* Author (2024).

TABLE 6 | Multivariate analysis of variance (MANOVA)—R output.

Annual_rainfall	Df:	Pillai:	Approx. *F*:	Num Df:	Den Df:	Pr(>*F*):	η^2
Residuals	1	0.34606	9.7902	2	37	0.0003867***	0.25
	38						
Annual_rainfall	Df:	Wilks:	Approx. *F*:	Num Df:	Den Df:	0.0003867***	0.25
Residuals	1	0.65394	9.7902	2	37		
	38						
Annual_rainfall	Df:	H-Lawley	Approx. *F*:	Num Df:	Den Df:	0.0003867***	0.25
Residuals	1	0.5292	9.7902	2	37		
	38						
Annual_rainfall	Df:	Roy:	Approx. *F*:	Num Df:	Den Df:	0.0003867***	0.25
Residuals	1	0.5292	9.7902	2	37		
	38						

Note: Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1.

TABLE 7 | Bonferroni post hoc test.

Contrast	Estimate	SE	df	*t*. ratio	*p*. value
Dryland Yields (kg) – Wetland yield (kg)	0.247	0.078	37.0	3.16	0.0033
Dryland yields (kg) – Annual rainfall (mm)	−0.391	0.105	37.0	−3.72	0.0006
Wetland yield (kg) – Annual rainfall (mm)	−0.638	0.131	37.0	−4.86	<0.0001

despite offering critical life support. Smallholder farmers reported that during the devastating drought of 1992, when the district and the country received very low rainfall below 200 mm, the Nyororo wetland provided critical life support to the Mberengwa and Filabusi communities as the sole source for domestic and livestock water. The communities underscored the need for wetland protection, implementation of the wise use approach and a coordinated wetland management system. Such measures yielded positive outcomes for people, climate and nature by retaining the provisioning services that supported community adaptation to climate change and variability impacts over the past decades.

4.2.3 | Seasonal Livelihoods Planning

The respondents of a household questionnaire survey indicated that different seasonal rainfall performances shaped livelihoods for smallholder farmers, as reported by 92% of respondents. When probed on priorities for wetland utilisation during the

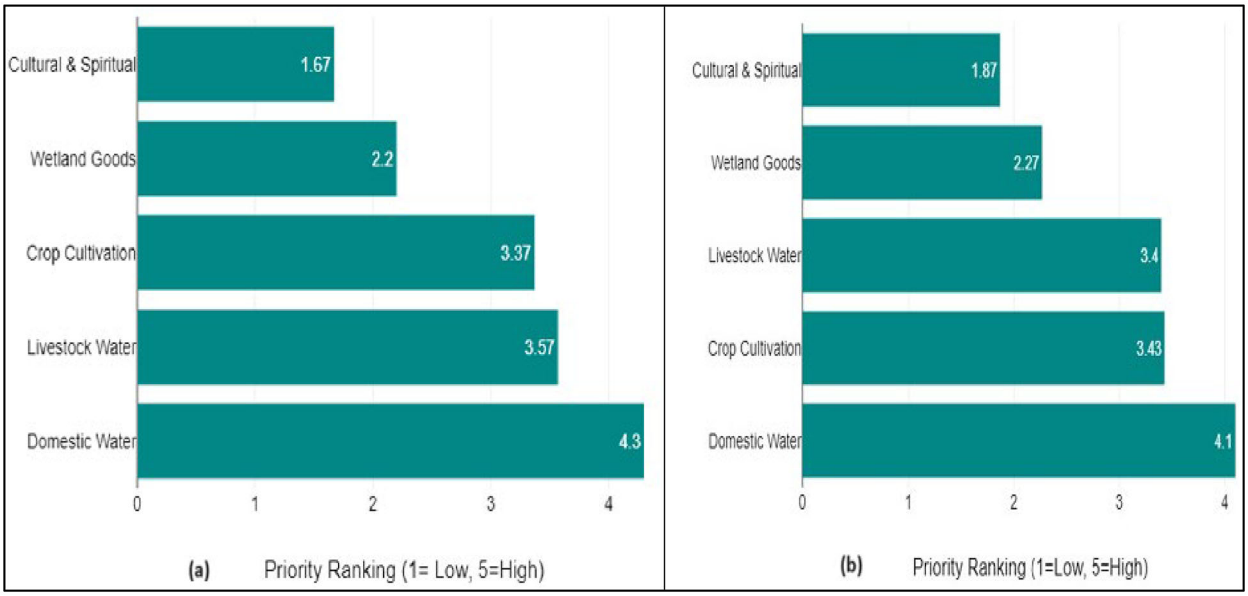

FIGURE 5 | Wetland utilisation priority for (a) below-normal rainfall year and (b) normal rainfall year. *Source:* Author (2024).

below-normal rainfall scenario (Figure 5a) and the normal rainfall season (Figure 5b), the respondents indicated that domestic water supply priority outweighs other wetland water uses. After prioritising domestic water, many farmers indicated that during the drought year (below normal rainfall), more water is required for livestock, followed by crop cultivation. Previous studies concurred that wetland utilisation by communities followed different patterns as influenced by seasonal climate (Mushore et al. 2021). Sustaining wetland species was the fourth priority, and the fifth priority was spiritual and cultural needs.

Smallholder farmers prioritise wetland water for domestic water supply during the good rainfall season (normal rainfall or above) and the drought season (below normal). The good seasonal rainfall year priority replaced the livestock water with crop cultivation prioritised in a drought year. When probed for an explanation, the consensus from the focus group discussion pointed out that livestock easily access other temporal surface water sources during a good rainfall season. Hence, the priority shifts towards irrigation for cultivated crops.

4.2.4 | Alternative and Diversified Livelihood Option

The findings of the FGDs and KIIs concurred with the smallholder farmers' views from the questionnaire survey that alternative and diversified livelihood options, which are not climate- and weather-indexed, present a greater opportunity for supporting community resilience. On a ranking scale, participants identified three alternative sustainable livelihoods and resilience options: the processing of non-timber forestry products (28%), wire fence making (46%) and the manufacturing of detergents (54%). Zimbabwe experienced shrinkages of food production zones, as identified by Manatsa et al. (2020). Due to shifting AEZs, wetlands in natural region V are shrinking in response to the identified pattern of aridity (Manatsa et al. 2020). This further supports the wetland size reduction findings from remote sensing (Figure 3). Diversification of smallholder livelihoods from agriculture-based to social entrepreneurship and ventures that are not weather- and climate-dependent was presented as a sustainable way for building community resilience to climate change in semi-arid areas.

5 | Practical and Theoretical Implications

Having identified key findings on climate change impacts on wetland agroecosystems and a set of resilience-building strategies, the following practical implications are key in taking the resilience-building framework to the next level.

- Financial mechanisms must be tailor-made to address local wetland users' needs, including incentivising adaptation strategies to reduce pressure on wetlands. The Ramsar Convention Secretariat (2010) revealed that wetlands' sustainability and resilience depend on funding to move the action. A part of the Nyororo wetland (Chivasa Village), protected by a CBO operating in the area, proved more resilient and offered more goods and services to the community than the unprotected site (Tovaka Village).
- Scientific and technological wetland assessments are required to support community conservation efforts with accurate information on biological species diversity and the general state of the wetland. Information on faunal and floral species for Nyororo wetland and threats from invasive species triggered positive conservation interests from local traditional leaders, wetland users and local authorities.
- The degradation of the Nyororo wetlands, as depicted by the shrinkage of the area covered by water, was also linked to a decline in the amount of water from the perennial wells. Because wetlands have direct linkages and connectivity with groundwater systems, wetland conservation requires a watershed approach that brings positive benefits and triple wins for the people, ecosystems and climate nexus.

- The AAP processes need strengthening to ensure that accurate information, decisions and policy frameworks can inform smallholder farmers' adaptive, absorptive and transformative capacities. Addressing the 'last mile' regarding access to climate information services should be prioritised to step up efforts to strengthen wetland agroecosystems' resilience for at-risk communities and ecosystems.
- The agroecosystems' concept emerged as an organising concept for promoting sustainable development goals that enhance the resilience of communities struggling with climate change, ecosystem loss, gender and water and land degradation. Policies and programmes should focus on promoting agroecosystems as an adaptation strategy for communities facing droughts and other extreme climatic challenges.

6 | Conclusion

Climate change has resulted in several challenges for farmer-managed wetland agroecosystems. Shrinkage in the size of wetlands has affected groundwater availability, whereas drought has increased wetland cultivation and grazing by livestock. Invasive species proliferation within the wetland explains the ongoing wetland ecosystem alteration and degradation. The study identified several strategies that are beneficial to smallholder farmers in promoting resilient wetland agroecosystems. The use of an EbA was identified in contexts where farmers created buffer zones to reduce interference with wetland water sources while implementing organic farming to increase food. Several social enterprises, including fruit tree propagation and indigenous poultry multiplication outside the wetland environment, were noted to have promoted increased smallholder farmers' income and reduced the pressure exerted on the Nyororo wetland by the growing population. The unavailability of sustainable financial mechanisms was reviewed as a key gap that requires attention to support wetland conservation and adaptation strategies. Policies, practices and research for realigning wetland conservation and climate change with seasonal livelihoods require prioritisation to prepare and align wetland-dependent communities for the changes brought by climate change and seasonal variability.

Author Contributions

Pascal Manyakaidze: conceptualisation, methodology, data collection, analysis, visualisation, report writing, review and editing. **Regis Musavengane**: review and editing. **Robert Maponga**: review and editing.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The research data supporting this original study can be requested from the author. Data will be shared on the basis of ethical considerations governing data distribution and protecting the identity of research participants.

References

Adeeyo, A. O., S. S. Ndlovu, L. M. Ngwagwe, M. Mudau, M. A. Alabi, and J. N. Edokpayi. 2022. "Wetland Resources in South Africa: Threats and Metadata Study." *Resources* 11, no. 6: 1–17. https://doi.org/10.3390/resources11060054.

Adhikari, G. P. 2021. "Calculating the Sample Size in Quantitative Studies." *Scholars' Journal* 4: 14–29. https://doi.org/10.3126/scholars.v4i1.42458.

Ajayi, V. O. 2017. "Primary sources of data and secondary sources of data." *Benue State University* 1, no. 1: 1–6.

Anticipation Hub. 2022. *Anticipatory Action in 2022: A Global Overview*. Anticipation Hub.

Arkkelin, D. 2014. "Using SPSS to Understand Research and Data Analysis." *Psychology Curricular Materials* 1: 194.

Attri, S. D., S. Tiwari, and K. Ray. 2017. "Challenges and Opportunities of Climate Change and Opportunities of Climate Change and Sustainable Agriculture: A Review." *Vayu Mandal* 43, no. 1: 23–37.

Babbie, E. 2011. *The Basics of Social Research*. 5th ed. Chapman University.

Bay, H. 2020. *Push–Pull to Control Fall Armyworm*.

Behnassi, M., O. Pollmann, and H. Gupta. 2018. "Climate Change, Food Security and Natural Resource Management: Regional Case Studies From Three Continents." In *Climate Change, Food Security and Natural Resource Management: Regional Case Studies From Three Continents*. Springer. https://doi.org/10.1007/978-3-319-97091-2.

Bhaga, T. D., T. Dube, M. D. Shekede, and C. Shoko. 2020. "Impacts of Climate Variability and Drought on Surface Water Resources in Sub-Saharan Africa Using Remote Sensing: A Review." *Remote Sensing* 12, no. 24: 1–34. https://doi.org/10.3390/rs12244184.

Biddle, C. 2021. *Introduction to Ayn Rand's Objectivism*. www.TheObjectiveStandard.com.

Brazier, A. 2018. *Climate Change in Zimbabwe. A Guide for Planners and Decision Makers*. 2nd ed. Konrad-Adenauer-Stiftung.

Bujang, M. A., and T. H. Adnan. 2016. "Requirements for Minimum Sample Size for Sensitivity and Specificity Analysis." *Journal of Clinical and Diagnostic Research: JCDR* 10, no. 10: YE01–YE06. https://doi.org/10.7860/JCDR/2016/18129.8744.

Chanza, N., and V. Gundu-Jakarasi. 2020. "Deciphering the Climate Change Conundrum in Zimbabwe: An Exposition." In *Global Warming and Climate Change*, edited by J. P. Tiefenbacher. IntechOpen.

Charan, J., R. Kaur, P. Bhardwaj, K. Singh, S. R. Ambwani, and S. Misra. 2021. "Sample size calculation in medical research: A primer." *Annals of the National Academy of Medical Sciences (India)*, 57, no. 02: 074–080.

Chikodzi, D., and R. C. Mufori. 2018. "Wetland Fragmentation and Key Drivers: A Case of Murewa District of Zimbabwe." *IOSR Journal of Environmental Science* 12, no. 9: 49–61. https://doi.org/10.9790/2402-1209014961.

Cochran, W. G. 1963. *Sampling Technique*. 2nd ed. John Wiley & Sons Inc.

Cohen, J. 1988. "Statistical Power Analysis for the Behavioral Science." In *Jurnal Sains Dan Seni ITS*. 2nd ed. Lawrence Erlbaum Associates, Publishers.

DATAtab Team. 2024. *DATAtab: Online Statistics Calculator*. DATAtab e.U. Graz, Austria. DATAtab Team. https://datatab.net.

Defe, R., and M. Matsa. 2021. "The Contribution of Climate Smart Interventions to Enhance Sustainable Livelihoods in Chiredzi District." *Climate Risk Management* 33: 100338.

Dube, C. 2018. *The Impact of Land Reform on Women's Livelihoods in Sub-Division a of Clonmore Farm—Mberengwa District in Zimbabwe*. University of the Witwatersrand.

Fakarayi, T., C. Mashapa, E. Gandiwa, and S. Kativu. 2015. "Pattern of Land-Use and Land Cover Changes in Driefontein Grassland Important

Bird Area, Zimbabwe." *Tropical Conservation Science* 8, no. 1: 274–283. https://doi.org/10.1177/194008291500800120.

FANPARN. 2017. *Policies and Practices for Climate-Smart Agriculture in Sub-Saharan Africa. Synthesis Report*. FANRPAN.

FAO. 2014. *Respecting* Free*,* Prior *and* Informed Consent*. Practical Guidance for* Governments*,* Companies*, NGOs,* Indigenous People *and* Local Communities *in* Relation *to* Land Acquisition. FAO.

FAO. 2018. *The Impact of* Disasters *and* Crises *on* Agriculture *and Food Security*. FAO.

Filho, W. L., J. May, M. May, and G. J. Nagy. 2023. "Climate Change and Malaria: Some Recent Trends of Malaria Incidence Rates and Average Annual Temperature in Selected Sub-Saharan African Countries From 2000 to 2018." *Malaria Journal* 22, no. 1: 248. https://doi.org/10.1186/s12936-023-04682-4.

Frischen, J., I. Meza, D. Rupp, K. Wietler, and M. Hagenlocher. 2020. "Drought Risk to Agricultural Systems in Zimbabwe: A Spatial Analysis of Hazard, Exposure, and Vulnerability." *Sustainability (Switzerland)* 12, no. 3: 752. https://doi.org/10.3390/su12030752.

Gardner, R. C. 2020. Global Wetland Outlook: State: State of the World's Wetlands and Their Services to People. In Ramsar convention secretariat (pp. 2020-5).

Government of Zimbabwe. 1998. Traditional Leaders Act. Chapter 29:17. Government of Zimbabwe.

Government of Zimbabwe. 2016. 2016–2017 Drought *Disaster Domestic* and *International Appeal* for *Assistance*. Government of Zimbabwe.

Government of Zimbabwe. 2024. Zimbabwe *Declares* El Nino *Drought* a *National Disaster*. Government of Zimbabwe.

Green Climate Fund. 2022. Building Climate Resilience of Vulnerable Agricultural Livelihoods in Southern Zimbabwe. Green Climate Fund. https://www.greenclimate.fund/project/fp127.

Guera, O. G. M., F. Castrejón-Ayala, A. Jiménez-Pérez, G. Sánchez-Rivera, L. Salazar-Marcial, and H. E. F. Moctezuma. 2021. "Effectiveness of Push—Pull Systems to Fall Armyworm (*Spodoptera frugiperda*) Management in Maize Crops in Morelos, Mexico." *Insects* 12, no. 4: 298.

Haradhan, M. 2018. "Qualitative Research Methodology in Social Sciences and Related Subjects." *Journal of Economic Development Environment and People* 7, no. 1: 23–48.

IFAD. 2014. *Small Farms, Big Impacts: Mainstreaming Climate Change for Resilience and Food Security*. IFAD.

Innes, J. E., and S. Connick. 2001. "Consensus Building as a Policy Making Strategy for Water Resources Management." UC Berkeley Technical Completion Reports, 15, 4. https://doi.org/10.11436/mssj.15.250.

Johnston, M. P. 2017. "Secondary Data Analysis: A Method of Which the Time Has Come." *Qualitative and Quantitative Methods in Libraries (QQML)* 3: 619–626. https://doi.org/10.1159/000479695.

Kabir, S. M. S. 2016. "Methods of Data Collection." *AORN Journal* 33, no. 1: 137–149. https://doi.org/10.1016/S0001-2092(07)69400-9.

Kansiime, M. K., I. Mugambi, I. Rwomushana, et al. 2019. "Farmer Perception of Fall Armyworm (*Spodoptera frugiderda* J. E. Smith) and Farm-Level Management Practices in Zambia." *Pest Management Science* 75, no. 10: 2840–2850. https://doi.org/10.1002/ps.5504.

Kielmann, K., F. Cataldo, and J. Seeley. 2012. Introduction to Qualitative Research Methodology: A Training Manual, produced with the support of the Department for International Development (DfID), UK, under the Evidence for Action Research Programme Consortium on HIV Treatment and Care (2006-2011). https://collaboration.worldbank.org/content/usergenerated/asi/cloud/attachments/sites/collaboration-for-development/en/groups/results-based-financing/documents/jcr:content/content/primary/blog/how_important_isthe-I7qE/Introduction%20to%20Qualitative%20Research%20Methodology%20-%20A%20Training%20Manual.pdf.

Lapan, S. D., M. T. Quartaroli, and F. J. Riemer. 2012. *Qualitative Research. An Introduction to Methods and Designs*. Jossey-Bass A Wiley Imprint.

Makarati, F., T. M. Ruhiiga, and L. G. Palamuleni. 2021. "Analysis of the Influence of Precipitation Patterns on Wetland Sizes in South-Eastern Zimbabwe." *African Journal of Environmental Science and Technology* 15, no. 10: 439–450. https://doi.org/10.5897/AJEST2020.2862.

Manatsa, D., T. D. Mushore, I. Gwitira, et al. 2020. *Revision Of Zimbabwe's Agro-Ecological Zones*. ISBN. https://www.researchgate.net/profile/Desmond-Manatsa/publication/349138874_Revision_of_Zimbabwes_Agro_Ecological_Zones_Government_of_Zimbabwe_under_Zimbabwe_National_Geospatial_and_Space_Agency_ZINGSA_for_the_Ministry_of_Higher_and_Tertiary_Education_Innovation_Science_and_/links/6023f2544585158939970126/Revision-of-Zimbabwes-Agro-Ecological-Zones-Government-of-Zimbabwe-under-Zimbabwe-National-Geospatial-and-Space-Agency-ZINGSA-for-the-Ministry-of-Higher-and-Tertiary-Education-Innovation-Science-and.pdf.

Manyakaidze, P., R. Musavengane, and M. Simatele. 2024. "Groundwater Development and Management Constraints in Drought Prone Chiredzi and Zvishavane Districts, Zimbabwe." *Climate Services* 34, no. 2024: 100467. https://doi.org/10.1016/J.CLISER.2024.100467.

Marambanyika, T., U. N. Mupfiga, T. Musasa, and K. Ngwenya. 2021. "Local Perceptions on the Impact of Drought on Wetland Ecosystem Services and Associated Household Livelihood Benefits: The Case of the Driefontein Ramsar Site in Zimbabwe." *Land* 10, no. 6: 587. https://doi.org/10.3390/land10060587.

Masih, I., S. Maskey, F. E. F. Mussá, and P. Trambauer. 2014. "A Review of Droughts on the African Continent: A Geospatial and Long-Term Perspective." *Hydrology and Earth System Sciences* 18, no. 9: 3635–3649. https://doi.org/10.5194/hess-18-3635-2014.

Meteorological Services Department. 2018. The Zimbabwe National Climate Outlook Forum. 2018/19 Seasonal Rainfall Forecast for Zimbabwe. Ministry of Environment, Water and Climate, Harare.

Meteorological Services Department. 2020. *The Zimbabwe National Climate Outlook Forum. 2020/21 Seasonal Rainfall Forecast for Zimbabwe*. Meteorological Services Department. 02 September 2020. https://cfuzim.org/wp-content/uploads/2020/09/msd2021.pdf Accessed: 09.09.2020.

Mishra, L. 2016. "Focus Group Discussion in Qualitative Research." *TechnoLearn: An International Journal of Educational Technology* 6, no. 1: 1–5. https://doi.org/10.5958/2249-5223.2016.00001.2.

Mugandani, R., M. Wuta, A. Makarau, and B. Chipindu. 2012. "Re-Classification of Agro-Ecological Regions of Zimbabwe in Conformity With Climate Variability and Change." *African Crop Science Journal* 20, no. 2: 361–369. https://doi.org/10.4314/acsj.v20i2.

Musasa, T., and T. Marambanyika. 2021. Drivers of wetland utilisation patterns and the current status of provisioning and cultural services In Driefontein and Intunjambili Wetlands, Zimbabwe. https://assets-eu.researchsquare.com/files/rs-407489/v1/43534bed-477a-4b05-ad68-17d5d5c6bc9d.pdf Accessed 02.07.2023.

Mushore, T. D., T. Mhizha, M. Manjowe, et al. 2021. "Climate Change Adaptation and Mitigation Strategies for Small Holder Farmers: A Case of Nyanga District in Zimbabwe." *Frontiers in Climate* 3: 1–10. https://doi.org/10.3389/fclim.2021.676495.

Mwenge, K. J., P. M. Bahal'okwibale, N. Budaza, et al. 2021. "Compendium of Community and Indigenous Strategies for Climate Change Adaptation—Focus on Addressing Water Scarcity in Agriculture." In *Compendium of* Community *and* Indigenous Strategies *for* Climate Change Adaptation. FAO. https://doi.org/10.4060/ca5532en.

Nyamadzawo, G., M. Wuta, J. Nyamangara, P. Nyamugafata, and N. Chirinda. 2015. "Optimizing Dambo (Seasonal Wetland) Cultivation for Climate Change Adaptation and Sustainable Crop Production in the Smallholder Farming Areas of Zimbabwe." *International Journal of Agricultural Sustainability* 13, no. 1: 23–39. https://doi.org/10.1080/14735903.2013.863450.

OCHA. 2024. Anticipatory Action. OCHA. https://www.unocha.org/anticipatory-action.

Ofori, S. A., S. J. Cobbina, and S. Obiri. 2021. "Climate Change, Land, Water, and Food Security: Perspectives From Sub-Saharan Africa." *Frontiers in Sustainable Food Systems* 5: 1–9. https://doi.org/10.3389/fsufs.2021.680924.

Oluwagbemi, O. O., J. T. Hamutoko, T. C. Fotso-Nguemo, B. O. K. Lokonon, O. Emebo, and K. L. Kirsten. 2022. "Towards Resolving Challenges Associated With Climate Change Modelling in Africa." *Applied Sciences (Switzerland)* 12, no. 14: 1–13. https://doi.org/10.3390/app12147107.

Onwuegbuzie, A. J., and K. M. T. Collins. 2007. "A Typology of Mixed Methods Sampling Designs in Social Science Research." *Qualitative Report* 12, no. 2: 281–316.

Quandt, A. 2021. "Coping With Drought: Narratives From Smallholder Farmers in Semi-Arid Kenya." *International Journal of Disaster Risk Reduction* 57: 102168. https://doi.org/10.1016/j.ijdrr.2021.102168.

R Core Team. 2024. *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing. https://www.R-project.org/.

Ramsar Convention Secretariat. 2010. "Wetlands: A Global Disappearing Act." *Fact Sheet 3.2* 3: 1–2.

Sachs, J. D. 2015. *The Age of Sustainable Development*. International Growth Centre London School of Economics. https://www.lse.ac.uk/Events/Events-Assets/PDF/2015/20150204-Jeff-Sachs-PPT.pdf Accessed: 12.12.2022.

The World Bank Group. 2020. Climate *Risk Country Profile*. Zimbabwe. The World Bank Group.

The World Bank Group. 2021. Climate Risk Country Profile Zimbabwe 2021. The World Bank Group.

Tol, R. S. J. 2021. "The Economic Impact of Weather and Climate." CESifo Working Paper No. 8946. SSRN. https://doi.org/10.2139/ssrn.3807009.

UNDP. 2015. *Building Resilience in Zimbabwe: Towards a Resilient Strategic Framework*. UNDP Zimbabwe.

UNOCHA. 2019. Humanitarian Appeal Revision 2019–2020. Zimbabwe. UNOCHA.

U.S. Geological Survey. (n.d.). Earth Explorer. Retrieved [Accessed 31/10/2021], from https://earthexplorer.usgs.gov.

Welt Hunger Hilfe, and Government of Zimbabwe. 2021. Drought Hazard Risk and Humanitarian Impact Analysis and Inventorisation of Forecast Models in Zimbabwe. Forecast Based Action—Drought Hazard Risk and Humanitarian Impact Analysis. RFQ Forecast Based Consultancy RFT No 258567. Final Report March 2021. https://www.anticipation-hub.org/Documents/Reports/WHH_ZWE_Drought_Hazard_Risk_and_Humanitarian_Impact_Analysis_and_Inventorisation_of_Forecast_Models.pdf Accessed 05.06.2023.

World Food Programme. 2021. *Integrated Context Analysis (ICA) ZIMBABWE (JUNE 2021)*. World Food Programme.

World Food Programme. 2022a. *A System to Anticipate and Address the Impacts of Drought in Zimbabwe An Overview of Partnerships, Capacity Strengthening and Activations Integrating Anticipatory Action Within Climate Risk Management*. World Food Programme.

World Food Programme. 2022b. Country Strategic Plan. ZIMBABWE. July 2022 - December 2026. World Food Programme.

Zimbabwe Resilience Building Fund. 2016. *Mapping of Selected Hazards Affecting Rural Livelihoods in Zimbabwe. A District and Ward Analysis*. UNDP Zimbabwe.

Zimbabwe Resilience Building Fund. 2017. *El Nino Southern Oscillation (ENSO) Cycle Events and Their Impacts in Zimbabwe*. UNDP Zimbabwe.

Government of Zimbabwe. 2020. *Zimbabwe Wetlands Policy 2020*. Ministry of Environment, Climate, Tourism and Hospitality Industry. https://kubatana.net/wp-content/uploads/2020/12/zimbabwe-Wetlands-Policy_ZeroDraftV4.pdf Accessed: 12.12.2022.

ZIMLAC. 2024 Zimbabwe Livelihoods Assessment Committee [ZIMLAC]. Rural Livelihoods Assessment Report. Harare, Zimbabwe: Food and Nutrition Council.

ZIMSTAT. 2016. *Framework for the Development of Environmental Statistics (FDES) in Zimbabwe*. Zimbabwe National Statistical Agency.

ZIMSTAT. 2022. *Zimbabwe 2022 Population and Housing Census Report*. Volume 2. Population Distribution by Ward. Zimbabwe National Statistics Agency.

ZIMVAC. 2010. *Zimbabwe Vulnerability Assessment Committee (ZimVAC) 2010 Zimbabwe Livelihoods Zone Profiles*. Food and Nutrition Council.

ZIMVAC. 2022. *Zimbabwe Vulnerability Assessment Committee (ZimVAC) 2022 Rural Livelihoods Assessment Report*. Food and Nutrition Council.

Supporting Information

Additional supporting information can be found online in the Supporting Information section.