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ORIGINAL ARTICLE

Smallholder rice farmers' resilience to water insecurity in Ogun State Nigeria

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Abstract

Agriculture in Nigeria is essentially rainfed. This makes smallholder rice farming households vulnerable to water insecurity caused by weather-related shocks. This research assesses the resilience of smallholder rice farmers to water insecurity in Ogun State, Nigeria using cross-sectional data collected through an open data kit-powered questionnaire. The aim of the research is to examine the connection between specific resilience capacities of smallholder rice farming households and water insecurity caused by weather-related shocks. To this end, a measure of resilience to water insecurity is developed that incorporates household investments in water management techniques using a categorical principal component analysis. The potential correlation between the dimensions of resilience capacities and different types of weather-related shocks is tested. The research shows that smallholder rice farming households in the study area have a low overall level of resilience. Moreover, farmers are able to absorb shocks but their ability to adapt to shocks is low. It is therefore important to improve the capacities of farming households to become more structurally resilient to water insecurity in the long run by enhancing their ability to adapt, mitigate the impact of shocks, and implement coping strategies.

Keywords Categorical principal component analysis · Rice farmers · Resilience capacities · Weather-related shocks · Nigeria

Introduction

Water is a crucial resource for agricultural production and is central to feeding the planet, providing livelihoods, and building resilience to climate shocks (Grey and Sadoff 2007; Cook and Bakker 2012; Dalin et al. 2017; Matthews et al. 2022; FAO 2023; Ringler et al. 2023; UN 2023, 2024). Water for agriculture can come directly from rainfall or can be secured through irrigation technologies, ranging from rainwater harvesting to large-scale schemes with extensive infrastructure (Parker et al. 2016; Matchaya et al. 2022). Agricultural production is a water-intensive industry, accounting for 85–90% of global surface and groundwater consumption with up to 70% for irrigation (FAO 2010, 2023; UNESCO 2012; Beek and Arriens 2014; Kummu et al. 2016; Luan et al. 2018; UN 2024).

Water insecurity can arise as a result of complex interactions between climatic variables including environmental factors (e.g. climate change; extreme weather-related shocks such as droughts and floods; and water pollution) and non-climatic drivers such as social factors (population growth; inequality in water access; and cultural practices), economic factors (inadequate investment in water infrastructure such as pipes, wells and reservoirs; inefficient water management; and agricultural practices), and political factors (weak governance; policy failures; water conflicts and corruption) (Grey et al. 2013; Oluwasanya et al. 2022; UN 2024; Zhang et al. 2024).

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Improved water security is key to improving households' resilience to climate variability and extreme weather events (Sadoff et al. 2015). Existing research has concentrated on the resilience of households to shocks and stresses in different contexts, including household resilience to food security shocks (Frankenberger et al. 2012; Béné et al. 2016; D'Errico et al. 2018; Ansah 2021; Bekele et al. 2021); household resilience in the context of disaster management, climate change, and environmental pressures (Mallick et al. 2011; Maikhuri et al. 2013; Thulstrup 2015; Eze 2018; Ratter 2018; Keating 2020); livelihood resilience (Manandhar and McEntire 2014; Tanner et al. 2015; Weldegebriel and Amphune 2017; Thái 2018); social-ecological system resilience (Folke 2016; Jarzebski et al. 2016); resilience in the context of poverty, gender dynamics, subjective well-being, and welfare for rural women (Parker et al. 2016; Zhang et al. 2024); and agropastoral household resilience in the presence of large-scale land investments (Silvestri et al. 2012; Bekele et al. 2021). However, studies on the resilience of households to water insecurity resulting from weather-related shocks are lacking.

This research aims to examine the connection between specific resilience capacities of smallholder rice farming households and water insecurity caused by weather-related shocks in Ogun State, Nigeria.. Agriculture serves as the main source of income for 80% of the rural poor in Nigeria. Rice (Oryza sativa L.) is an important food crop in the world and serves as a staple for more than half of the world's population (Danbaba et al. 2019; Pokhrel et al. 2020). However, crop production in Nigeria is experiencing many hazards related to climate change and extreme weather events (Ifeanyi-Obi et al. 2012; Ifeanyi-Obi 2016). Depletion of water resources and unpredictable rainfall patterns are having a significant impact on production systems, leading to crop failures. Nearly 80% of Nigerian farmers were estimated to have been affected by the effects of drought and flooding in 2020 (Premium Times 2021). To reduce the negative effects of water insecurity and strengthen resilience, farmers can invest in agricultural water management techniques to limit the loss of access to water (e.g. rain harvesting) or limit the risk of flood damage (e.g. drainage). This research therefore develops a measure of resilience to water insecurity that incorporates households' investments in such management techniques. Furthermore, we test the potential correlation between the dimensions of resilience capacities and different types of weather-related shocks.

This research contributes to the literature, first, by offering a conceptual framework that links specific resilience capacities of smallholder rice farming households with water insecurity caused by weather-related shocks building on the TANGO International (2018) resilience framework. Next, it develops a resilience capacity index at household level using an empirical data set that was specifically collected to analyze the connection between specific resilience capacities and water insecurity. While previous studies have used the TANGO methodology in the context of household food insecurity, this study adapted the TANGO methodology specifically within the context of water insecurity which incorporates household investments in water management techniques like rain harvesting and drainage, using a categorical principal component analysis (Upton et al. 2022; Zhang et al. 2024). Furthermore, it tests the correlations between resilience capacities and different types of weather-related shocks. By doing so, this research bridges the existing knowledge gap by offering new insights and methodologies that enhance the understanding of resilience in the context of water insecurity and also provides valuable implications for theory and practice informing more effective interventions and policies to deal with weather-related shocks (Frankenberger and Nelson 2013; Barrett and Constas 2014).

Conceptual framework

The concept of resilience

The conceptual framework guiding this research is based on the resilience framework, a holistic framework that examines how systems, households, or communities absorb, adapt to, and recover from the effects of disturbances, including weather-related shocks (Folke 2006; Alinovi et al. 2008, 2010; FAO 2016; TANGO International 2018; Bekele 2022). It encompasses the ability to not only bounce back to a previous state of well-being but also to transform structures and strategies to better withstand future shocks (Thulstrup 2015; FAO 2016; Thái, 2018). Definitions from various sources emphasize resilience as the ability to anticipate, prepare for, cope with, adapt to, and recover from the impact of shocks in a timely and efficient manner, thereby reducing chronic vulnerability, promoting inclusive growth, ensuring the preservation, restoration or improvement of its essential basic structures and long-term functionality (IPCC 2012; USAID 2012; Frankenberger et al. 2013; World Bank & GFDRR 2013; IFRC 2014; FAO 2016; TANGO International 2018). Hence, resilience integrates adaptive, absorptive, and transformative capacities to effectively prepare for and manage the effects of climate change and climate-related hazards and risks (Folke 2006; Alinovi et al. 2008, 2010; Tanner et al. 2015; FAO 2016; Convertino & Valverde 2019; Roberts et al. 2019; Bekele 2022). In the context of this study, resilience is defined as *"the ability of a household to absorb, adapt to, and recover from disturbances, including the effects of weather-related shocks, while also transforming to better handle future stresses through integrating investments in water management techniques to enhance resilience and* *the ability to maintain functionality despite weather-related shocks".*

It should be noted that this research follows a social science perspective on the concept of resilience. In the domain of ecology, adaptive capacity is often viewed as a component of vulnerability rather than of resilience. For instance, as highlighted in Lecina-Diaz et al. (2024), "*resistance and recovery describe resilience to a disturbance with an explicit temporal sequence, whereas vulnerability focuses on susceptibility and adaptive capacity, with temporality frequently being implicit*".

The concept of water (in)security

Water security is crucial to achieving sustainable and inclusive growth. Several authors claim that water issues are fundamentally wicked problems, that is, problems so complex that attempting to fix one part usually makes another part worse especially regarding resource poor smallholder rice farmers. Water insecurity can exist in terms of both water shortages (from droughts) and excess water (from floods). An appropriate measure of agricultural water security therefore incorporates different aspects of weather-related shocks and depends on local conditions and site-specific coping capacity (Vorosmarty et al. 2005; Scott et al. 2013; Shinde 2016; Gerlaka et al. 2018).

Water security has no single definition, varying with purpose and perspective (Cho et al. 2010; Forouzani and Karami 2011; Bakker 2012; Cook and Bakker 2012; Bitterman et al. 2016; Adeel 2017; Gordon 2018; UN 2024). Three prominent definitions of water security (Holmatov et al. 2017) are: (i) every person has access to enough safe water at affordable cost to lead a clean, healthy and productive life while ensuring that the natural environment is protected and enhanced (Cook and Bakker 2012); (ii) availability of an acceptable water quantity and quality for health, livelihoods, ecosystems and production, coupled with an acceptable level of weather-related shocks to people, environments and economies (Grey and Sadoff 2007; WWC and OECD 2015); and (iii) the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being and socioeconomic development, for ensuring protection against water-borne pollution and weather-related shocks, and for preserving ecosystems in a climate of peace and political stability (UNU 2013).

A situation where the conditions in the aforementioned definitions are not fulfilled gives rise to water insecurity. In view of the focus of this study, agricultural water insecurity is defined as *"the inability of a household to access water resources to support agricultural production and to apply plans to ensure safety from weather-related shocks"*.

The concept of shocks

Shocks are "*external short-term deviations from long term trends that have substantial negative effects on people's current state of well-being, level of assets, livelihoods, safety or their ability to withstand future shocks*" (Sagara 2018). Shocks can be slow-onset like drought, or relatively rapid onset like flooding, disease outbreak, or market fluctuations. A shock is "*any event which may disrupt the normal functions of socioeconomic agents and/or their activities, impose challenges and threaten household food security*" (Ansah et al. 2019). Weather-related shocks affect agricultural production through floods, droughts, and storm surges with subsequent impacts on rural livelihoods (Birthal et al. 2015). This study accounts for commonly experienced shocks and severity of the shocks experienced by households in the study area.

Figure 1 presents a conceptual framework for resilience of smallholder rice farming households to water insecurity, emphasizing the relationships between water insecurity, characterized by weather-related shocks in terms of non-climatic variables and climatic variables; and household resilience characterized by resilience capacity indicators in terms of absorptive capacity, adaptive capacity and transformative capacity. In the remainder of the study, the focus will be on climatic variables, that is, water scarcity (drought) and excess (flooding) and on household resilience which involves coping, adjusting, and transforming in the face of disturbances, aiming for long-term sustainability and reduced chronic vulnerability.

Materials and methods

Study area

Nigeria comprises of 36 administrative divisions known as States, along with a Federal Capital Territory (Abuja). The 36 States are stratified into 6 geo-political zones (North-west, North-east, North-central, South-west, South-south and South-east). This classification is based on pre-colonial ancient dynasties, tribal affiliations and ethnic groupings. The South-west zone which includes Ogun State, had an estimated number of inhabitants of 35,068,876 in 2018, with about 75% residing in rural areas and predominantly engaged in agriculture (WPR 2018). This study was conducted in Ogun State, which comprises 20 local government areas and covers 16,762 square kilometres with 80% of the land being arable (NBS 2019). The State is geographically positioned between latitudes 6.2°N and 7.8°N and longitudes 3.0°E and 5.0°E. The climate is typically tropical, characterised by distinct wet and dry seasons. The dry season extends from November to March, while the rainy season lasts from

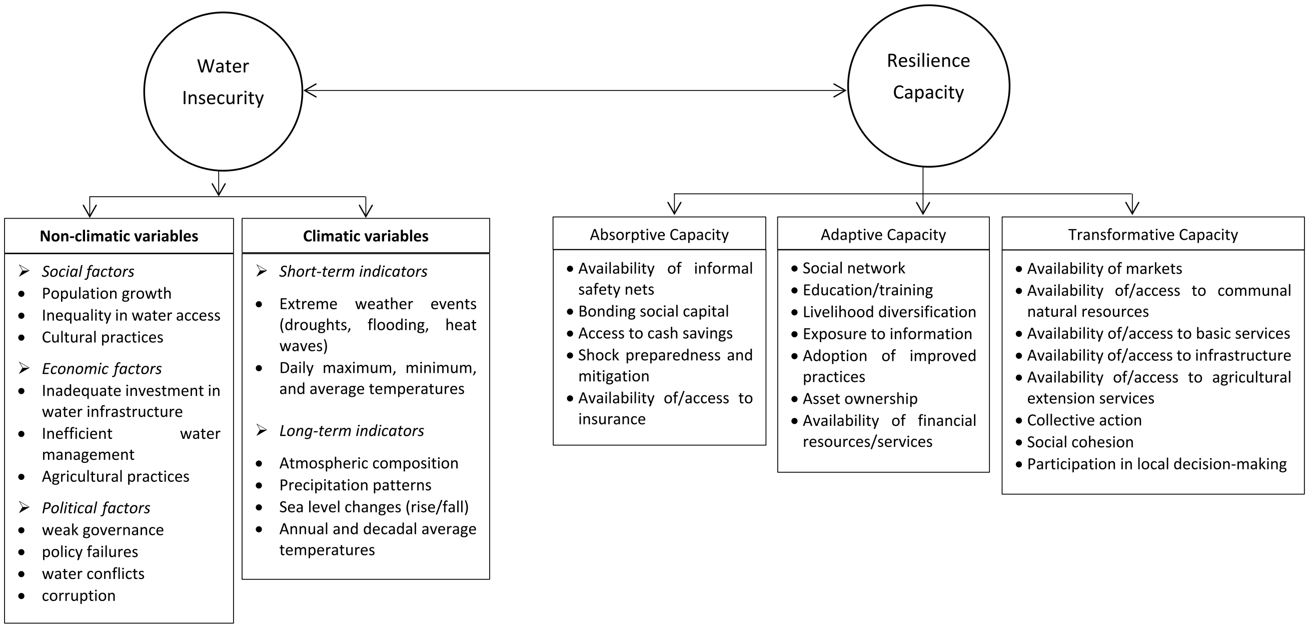

Fig. 1 Conceptual framework for resilience of smallholder rice farming household to water insecurity. Source: adapted from Folke (2006), Alinovi et al. (2008), Alinovi et al. (2010), FAO (2016), TANGO International 2018, and Bekele (2022)

April to October. The mean annual rainfall varies across the State, ranging from 105mm in the northern areas to 128mm in the southern parts. Relative humidity fluctuates between 76% during the dry season and 95% during the wet season. Temperatures range from a monthly mean of 23°C in July to 32°C in February. (NBS 2019; Igwenagu 2021; Nigeria Galleria 2021; WPR 2022). The vegetation transitions from mangrove swamps in the southern coastal areas to rainforests in the central regions, and savanna in the northern parts. The diverse vegetation supports a variety of agricultural activities. Notable crops cultivated include cassava, maize, rice, yam and cocoyam. The study area, primarily a rural setting, has a vast network of water bodies (rivers and streams) but it is also prone to frequent droughts and floods impacting agricultural productivity. Figure 2 shows the location of the study area in Nigeria.

Data collection

Cross-sectional data were obtained through an open data kit-powered questionnaire during the 2020/2021 agricultural season from rice farming households in Ogun State, Nigeria. The study's sampling procedure was based on the structure of Ogun State Agricultural Development Programme (OGADEP), which stratifies the state into four agricultural zones (Abeokuta, Ikenne, Ilaro and Ijebu-Ode). Each zone is further divided into blocks, and the blocks further subdivided into cells; with cells comprising of a cluster of villages (OGADEP 2005). A multi-stage sampling method was adopted, involving 200 smallholder rice farming households. In the first stage, Abeokuta and Ikenne zones were purposively selected based on rice production intensity. In the second stage, one block (Wasimi and Obafemi-Owode, respectively) was selected from each of the selected zones. The third stage entailed a purposive selection of one cell (Wasimi and Mokoloki, respectively) from each selected block. Finally, in the fourth stage, 100 smallholder rice farming households were randomly selected from each selected cell using the OGADEP's list of smallholder rice farming households as the sampling frame. In total, 183 smallholder rice farming households were retained in the study after excluding households with incomplete information. Data were obtained on the households' socio-demographic and farm level characteristics, agricultural production inputs and output, available water sources (e.g., borehole, deep well, streams and harvested rain), water management practices, types of weather-related shocks experienced, investment in water security and coping strategies.

Methods for analysis

Measuring resilience

This research measures resilience by relying on the TANGO approach (TANGO International 2018). TANGO calculates a resilience capacity index based on the resilience capacity dimensions of absorptive capacity (ability to minimize exposure to shocks and recover quickly when exposed), adaptive capacity (ability to make informed decisions about alternative livelihood strategies based on changing conditions) and

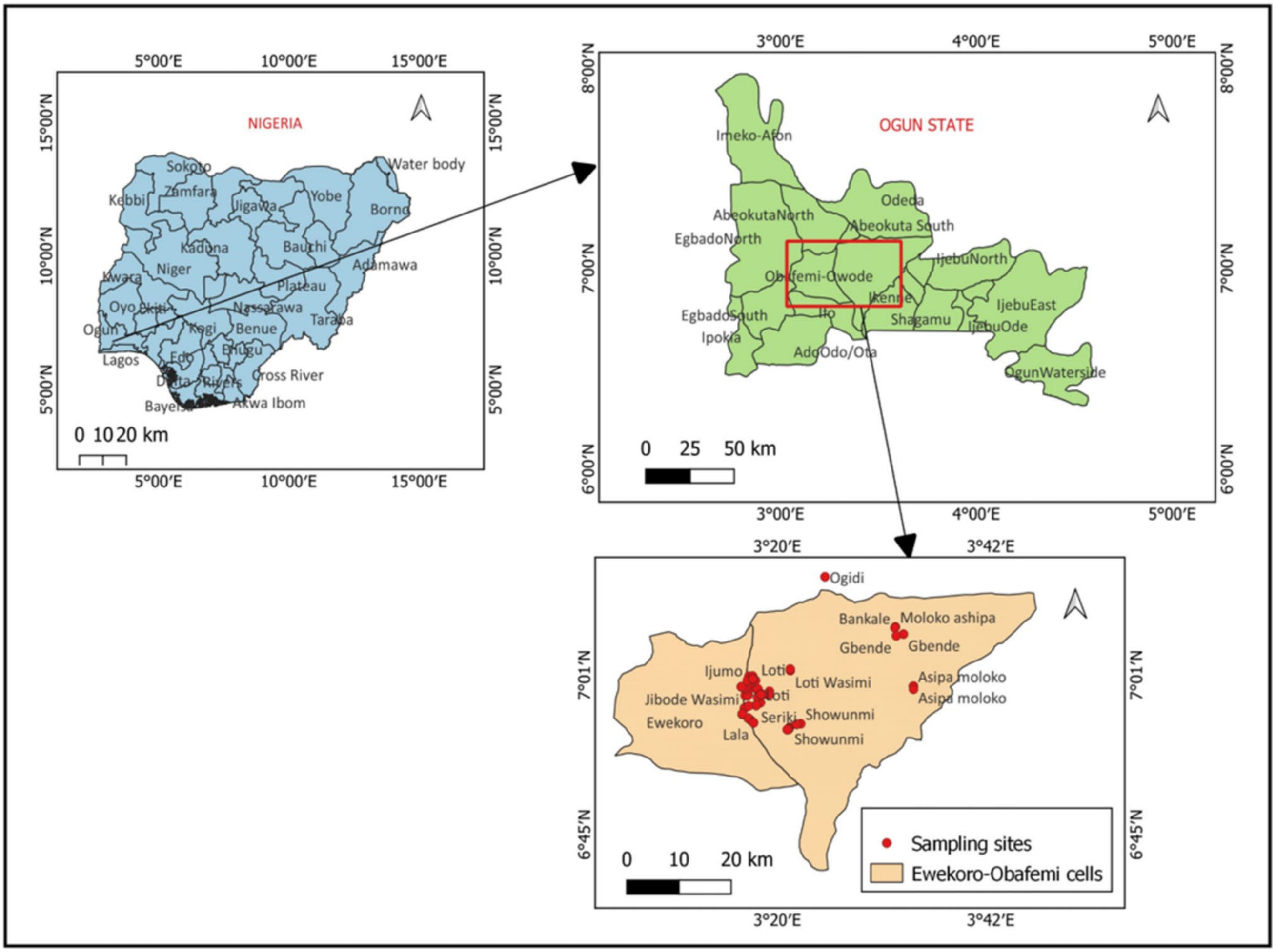

Fig. 2 Map of Nigeria showing Ogun State and the location of the study sites. Source: Drawn with QGIS using study location GIS, the country boundary shape file of Nigeria was downloaded from https://www.diva-gis.org/gdata

transformative capacity (the system-level enabling conditions for lasting resilience) and their respective indicators, by employing exploratory factor analysis (Béné et al. 2012, 2016; Frankenberger et al. 2012, 2013; Maleksaeidi et al. 2016; TANGO International 2018).

Household resilience capacity (RC_i) for the i^{th} household in this study is specified in Eq. (1) as follows:

$$RC_i = f(ABC_i, ADC_i, TC_i) \quad (1)$$

where: RC_i[1] = resilience capacity; ABC_i = absorptive capacity; ADC_i = adaptive capacity; and TC_i = transformative capacity. Resilience is not observable as such, and is considered a latent variable depending on the terms on the right-hand side of the equation.

The resilience capacity index is calculated in three steps.

STEP 1: Computing index weights

While the TANGO approach used exploratory factor analysis, this research uses categorical principal component analysis (CATPCA) with optimal scaling to derive the three resilience capacities (ABC, ADC and TC). CATPCA is appropriate for data reduction when variables are categorical and the researcher is concerned with identifying the underlying components of a set of variables while maximizing the amount of variance accounted for in those items by the principal components. The primary benefit of using CATPCA over traditional principal component analysis (PCA) is the lack of assumptions associated with CATPCA. It does not assume linear relationships among numeric data nor does it require multivariate

[1] In practice, indexes of all three dimensions of resilience capacity—absorptive capacity, adaptive capacity and transformative capacity—are first calculated using categorical principal component analysis and then combined into an overall index of resilience capacity. Thus, RC is estimated by separately estimating ABC, ADC and TC (which are themselves latent variables because they cannot be directly observed in the survey) and then summing up the three resilience capacities. This is explained in more detail in STEPS 1 to 3.

normal data (Linting and Van der Kooij 2012; Kemalbay and Korkmazoğlu 2014; Starkweather 2018). Cronbach's alpha is used to assess scale reliability (Guttman 1945; Cronbach 1951; George and Mallery 2003). The model summaries for the three capacities are presented in Appendix A.

STEP 2: Standardization

The indicators used to measure household resilience capacity are specified in Appendix B. The sources and selection of indicators for each dimension of resilience are based on a comprehensive review of relevant literature and consideration of local context. A range of sources, including TANGO International (2018) and other relevant studies were reviewed to ensure a comprehensive and robust set of indicators (Upton et al. 2022; Zhang et al. 2024). Additionally, local indicators relevant to smallholders' resilience to water insecurity were incorporated to capture specific regional aspects. Indicators were chosen based on their relevance to the resilience dimensions, their ability to capture key aspects of each capacity, and their empirical support from existing research. Each indicator was evaluated for its contribution to understanding the respective dimension of resilience, ensuring that the selected indicators comprehensively reflect the theoretical and practical aspects of the capacities being measured. Indicators are standardized by multiplying each indicator value with the corresponding factor loading obtained from the CATPCA (Appendix C). The standardized values for all the indicators are summed and then averaged as shown in Eqs. (2a, 2b, and 2c):

$$RC_{ABCi} = \sum_{j=1}^{n} \left(x_{ji}\gamma_{ji}\right)/n \quad (2a)$$

$$RC_{ADCi} = \sum_{j=1}^{n} \left(x_{ji}\gamma_{ji}\right)/n \quad (2b)$$

$$RC_{TCi} = \sum_{j=1}^{n} \left(x_{ji}\gamma_{ji}\right)/n \quad (2c)$$

where RC_{ABCi}, RC_{ADCi}, and RC_{TCi} are the resilience capacity indexes for the i[th] household, x is the indicator value of each resilience capacity indicator (for ABC_i, ADC_i or TC_i), γ is the factor loading, j is the type of indicator, and n is the total number of indicators; $i = 1, 2, \ldots, 183$, $j = 1, 2, 3, \ldots, n$; $\gamma > 0$. When estimating absorptive capacity (ABC_i), adaptive capacity (ADC_i) and transformative capacity (TC_i), n is 19, 13 and 14, respectively.

STEP 3: Calculating the overall resilience capacity index

The overall resilience capacity index is the aggregate of the sum of standardized values of the absorptive, adaptive and transformative capacity indexes, as shown in Eq. (3).

$$RCi = ABCi + ADCi + TCi \quad (3)$$

A min–max scaling procedure is used to transform RC_i into a scale ranging between 0 and 1 (Eq. 3).

$$RCi* = (RC_i - RCmin)/(RCmax - RCmin) \quad (4)$$

where RC_i* is the scaled resilience capacity index for the i[th] household, RC_i is the resilience capacity index value of the i[th] household, $RCmin$ and $RCmax$ are the minimum and maximum index values for the resilience capacity index in the whole sample, respectively.

In addition, two categories of households are created based on their resilience capacity, by taking the median as cut-off value of the distribution. Below the cut-off value, households are categorized as having low resilience capacity while above this value, they are categorized as having high resilience capacity.

t-test, chi-square analysis, correlation analysis and analysis of variance (ANOVA)

Significant differences in terms of socio-economic characteristics between farmers in low and high resilience capacity categories are examined using t-test and chi-square statistics. Pearson correlation analysis is used to assess the strength of association between household resilience capacities and the occurrence of droughts and floods (in the last five years). A one-way ANOVA procedure is used to analyze the variation in household resilience indexes (absorptive, adaptive, transformative, and overall resilience). Households are assigned to one of four groups based on their reported exposure to weather-related shocks over the last five years (flood, drought, both flood and drought, and no weather-related shocks experienced). These groups form the basis for the ANOVA analysis, which allows testing the hypothesis that the mean resilience indexes are the same across the four groups of households. In addition, a multiple comparisons analysis is performed to test group-by-group differences in the mean resilience indexes.

Results

Socio-economic characteristics of the smallholder rice farming households

Table 1 reports the socioeconomic characteristics of households in the study area. Among the 183 sampled rice farming households, 67 are female and 116 are male, with 86.3% being married and the average age being below 50 years. Additionally, 71.0% of the farmers have formal education, and the average household size is 9 people. The average

Table 1 Rice farming households' socio-economic variables ($n = 183$)

Characteristic	Freq	Min	Max	Mean	Std. Dev
Sex (1 = female; male = 2)	67(36.6)	-	-	-	-
Marital status (married = 1)	158(86.3)	-	-	-	-
Age (years)	-	16	74	45.3	14.181
Education (1 = formal education; 2 = informal education)	130(71.0)	-	-	-	-
Household size (number)	-	1	32	9	4.662
Years spent in community (years)	-	1	71	28.8	18.411
Rice farming experience (years)	-	1	62	22.3	15.671
Volume of credit (Nigerian naira)	-	6000	2,000,000	201,468.1	213,407.40
Farm size (ha)	-	0.2	30	2.6	2.901

Numbers in parenthesis are percentages. Other marital status categories: divorce = 2; widow = 3; single = 4

Source: Computed from field survey data

farm size is about 3ha and the average credit[2] volume is N201,468.10.

Resilience of smallholder rice farming households to water insecurity

Factor loadings represent the importance of each indicator's contribution to the resilience capacity index. A factor loading (γ) greater than 0.6 contributes strongly, while those with a value of less than 0.3 indicate a weak contribution to resilience capacities. Incidence can be interpreted as the proportion of households using each of the indicators.

Table 2 reports the absorptive capacity of rice farming households. It shows that informal safety nets, bonding social capital, and shock preparedness indicators strongly contribute to the absorptive capacity of smallholder rice farming households. However, collection of runoffs from flood, irrigation use, construction of flood dykes, control levees, flood retention areas and drainage canals embankment, and crop insurance contribute poorly to household absorptive capacity, with prevalence in less than 10% of the sampled households. Social networking, training, adoption of improved farming practices, financial resources, and exposure to information provide a strong contribution to households' adaptive capacity as presented in Table 3, while educational status, livelihood diversification, and major productive asset owned, are less impactful. The indicators of collective action, social cohesion, participation in local decision-making, access to infrastructure, communal natural resources and agricultural extension services enhance households' transformative capacity while access to basic services contributes less (Table 4).

Description of household resilience by household socio-economic characteristics

Table 5 compares the socio-economic characteristics of households in different resilience capacity categories. Households in both resilience categories are comprised of farmers in their mid-forties. Female farmers are more prevalent in low resilience capacity households. Except for transformative capacity, credit volumes are lower in households with low resilience. Generally, households attain 31.4% of the overall resilience capacity with the highest contribution from absorptive capacity (38.4%) and the lowest from adaptive capacity (19.7%). Table 6 shows that younger farmers are linked to low absorptive and transformative capacities with no significant difference in the gender being observed in resilience capacities. More married farmers are found in households with high adaptive capacity. Households with low resilience tend to have less community experience, obtain less credit, and have a larger farm size.

Prevalence of weather-related shocks experienced by smallholder rice farming households

Figure 3 reports the types of weather-related shocks faced by households in the last 5 years, with 97.3% of the households encountered at least one weather-related shock, with drought being the most common (67.8%). A small percentage of the households, however, reported no weather-related shocks. In the past 12 months, as shown in Fig. 4, 71.0% and 48.1% of the households rarely experienced drought and flooding respectively, while 23.5% and 8.2% always faced drought and flooding, respectively.

[2] In the survey year 2021, one Euro equals 454.55 Nigerian Naira (N).

Table 2 Smallholder rice farming household's (ABC) index

Indicators	Factor loadings	Incidence (%)
Availability of informal safety nets		
Relying on assistance from friends & relatives	0.607	31.1
Membership of community-based organizations	0.449	33.1
Bonding social capital		
Using a diverse workforce	0.600	36.9
Sharing of Resources & Technology	0.487	21.9
IWICS/involvement/time involvement ABC	0.617	64.6
IWICS/involvement/money involvement ABC	0.659	59.3
Access to cash savings		
Information on credit use (access) ABC	0.508	25.8
Shock preparedness and mitigation		
Rain water harvesting	0.576	14.8
Use of irrigation	0.205	4.1
Collection of runoffs from flood	0.232	3.3
Construction of flood dykes, control levee, flood retention areas, groynes, drainage canals embankment [dam/river]	0.165	7.1
Sustainable land management practices (e.g. Crop rotation and inter cropping)	0.501	17.8
Adding new crop/changing crop species	0.501	11.7
Change timing of crop planting	0.600	18.0
Use of drought tolerant/resistant crop varieties/seeds	0.333	11.7
Pest and disease control	0.688	35.8
Farm waste disposal	0.605	24.3
Soil & erosion control	0.462	17.2
Availability of/access to insurance		
Crop insurance	0.170	1.1
Cronbach's Alpha	0.914	-
Eigenvalue	7.443	-
% variance	39.17%	-

ABC = absorptive capacity

Source: Indicators adapted from TANGO International (2018) and Maleksaeidi et al. (2016); factor loadings computed from field survey data (2021)

Household resilience capacity dimensions and weather-related shocks phenomena

Table 7 shows the correlation between household resilience capacity dimensions and exposure to weather-related shocks. It shows that there is no significant association between the occurrence of floods and droughts and the resilience capacity of rice farming households in the study area. This implies that the resilience capacity of these households (i.e. their ability to withstand and recover from adverse events), is not significantly affected by the floods and droughts they experience. The ANOVA results in Table 8 show that there are significant differences in the mean adaptive, transformative, and overall resilience capacities across groups of households with a different exposure to weather-related shocks, while absorptive capacity shows no significant variation. Table 9 reveals that households that did not experience any weather-related shocks in the last 5 years exhibit higher resilience than those that experienced floods, droughts, and both shocks, with drought having the more severe impact. Surprisingly, those households that experienced only droughts have lower resilience capacity than those that experienced both shocks (i.e., floods and droughts). This may indicate that exposure to multiple shocks drives these households to adopt strategies that enhance their transformative and overall resilience capacities to mitigate the effects of extreme weather events.

Discussion

Issues in smallholder rice farming households' resilience and water insecurity

The study investigates the relationship between specific resilience capacities of smallholder rice farming households

Table 3 Smallholder rice farming household's (ADC) index

Indicators	Factor loadings	Incidence (%)
Social network		
Social networking	0.871	15.8
Education/training		
Acquire awareness of local action adaptation	0.812	12.8
Assessment of early warning service/system	0.756	24.7
Prepares & trains for long-term changes	0.786	6.0
Prepares & trains for short-term changes	0.707	10.4
Participate in risk & vulnerability planning	0.773	7.4
Educational status	0.042	71.0
Livelihood diversification		
Livelihood diversification ADC	0.101	23.2
Exposure to information		
Access to/ownership of communication device ADC	0.382	38.0
Adoption of improved practices		
Farming Practice	0.761	26.5
Asset ownership		
Major productive assets owned (fixed inputs/working capital) ADC	0.173	50.1
Availability of financial resources/services		
Information on credit use (access) ADC	0.655	25.8
Can access funds dealing with short-term disasters	0.454	11.5
Cronbach's Alpha	0.918	-
Eigenvalue	6.537	-
% variance	50.28%	-

ADC = adaptive capacity

Source: Indicators adapted from TANGO International (2018) and Maleksaeidi et al. (2016); factor loadings computed from field survey data (2021)

and water insecurity caused by weather-related shocks in Ogun State, Nigeria. While other factors than water can influence resilience capacities of smallholder rice farming households, this research focuses specifically on factors relating to water insecurity.

The findings highlight the distinct contributions of the three key indicators of resilience, absorptive, adaptive, and transformative capacities to overall household resilience. The study finds that absorptive capacity is considered the most important of the three indicators in enhancing household resilience. This contrasts with the findings of Zhang et al. (2024), who rank absorptive capacity as the least significant of the three resilience capacities and highlight its relative weakness in the resilience of smallholder farming households. Absorptive capacity is primarily shaped by informal safety nets and bonding social capital, especially in regions like Nigeria, where formal crop insurance schemes are not accessible. This aligns with the findings of Bekele et al. (2021), who claim that social safety nets best contribute to households' absorptive capacity in the absence of formal insurance schemes. The study further supports findings by Matchaya et al. (2022), who highlight the importance of insurance as an important strategy for managing agricultural risks. However, the absence of crop insurance schemes, poor shock preparedness, and inadequate mitigation strategies, such as limited irrigation and embankment construction, significantly weaken resilience among smallholder farmers. In this context, Matchaya et al. (2022) and Bekele et al. (2021) claim that households with access to irrigation can better absorb disturbances and reduce water stress from weather-related shocks. Consequently, improving access to irrigation, enhancing shock preparedness and mitigation facilities, and expanding insurance schemes would strengthen resilience to weather-related shocks.

Adaptive capacity enables smallholder farming households to adjust and recover in response to shocks. This study finds that adaptive capacity is the least contributing dimension to household resilience. This contrasts with other studies that emphasize its strong correlation with overall resilience (Gallopin 2006; Deressa et al. 2008; Silvestri et al. 2012; D'Errico et al. 2018; Zhang et al. 2024). The observed low adaptive capacity can be attributed to low education levels, limited livelihood diversification, and inadequate productive assets which are some of the characteristics of

Table 4 Smallholder rice farming household's (TC) index

Indicators	Factor loadings	Incidence (%)
Availability of markets		
Market access	0.425	10.4
Availability of/access to communal natural resources		
Water Sources	0.608	9.3
Availability of/access to basic services		
Community centers access	0.347	23.2
School access	0.277	57.4
Health centers access	0.068	11.2
Access to nearby public utilities	0.494	24.0
Access to nearby public basic education	0.483	40.4
Availability of/access to infrastructure		
Access to/ownership of communication device TC	0.616	38.0
Availability of/access to agricultural extension services		
Access to nearby extension services	0.570	26.0
Collective action		
Participate in age group or social institution	0.714	30.6
Social cohesion		
IWICS/involvement/time involvement TC	0.698	64.6
IWICS/involvement/money involvement TC	0.700	59.3
Participate in risk & vulnerability planning	0.560	7.4
Participation in local decision-making		
Participate in governance	0.663	17.2
Cronbach's Alpha	0.914	-
Eigenvalue	6.610	-
% variance	47.21%	-

TC = transformative capacity

Source: Indicators adapted from TANGO International (2018) and Maleksaeidi et al. (2016); factor loadings computed from field survey data (2021)

Nigerian farmers. These factors directly weaken resilience by reducing households' ability to adapt to and recover from shocks, increasing their vulnerability to disruptions and diminishing their capacity for long-term stability. In the local context, social networking, training, awareness of early warning services, access to and ownership of communication devices, and improved farming practices are crucial for enhancing household adaptive capacity, as noted by Chamdimba et al. (2020). This study further emphasizes the vital role of financial resources in enabling rural smallholder farming households to withstand and recover from shocks. Strategies such as providing loan subsidies and encouraging financial institutions to expand services in rural areas are essential for improving access to financial resources, thereby enhancing adaptive capacity and mitigating the effects of shocks. The findings of this research align with D'Errico and Di Giuseppe (2018), Felkner et al. (2022), and Zhang et al. (2024), who also underscore the importance of financial resources in resilience building.

The primary contributors to the transformative capacity of household resilience include social cohesion, collective action, local decision-making participation access to infrastructure, communal natural resources and agricultural extension services. They help smallholder farming households to transform structures and strategies to withstand future shocks (Béné et al. 2012; Thái, 2018; Zhang et al. 2024). However, the relatively low transformative capacity in the study area suggests that farming households' ability to cope with water insecurity is poor. This finding is consistent with Bekele et al. (2021) and Melketo et al. (2021) who emphasize the vulnerability of smallholder farmers in sub-Saharan Africa, particularly in response to climate-induced stressors.

An interesting pattern emerged regarding age and resilience. Older farmers generally possess higher absorptive and transformative capacities, possibly due to their greater access to informal safety nets and involvement in collective action within communities. This finding can be explained by the cultural factors prevalent in many African societies, such as gerontocracy or patriarchy, which empower older individuals in community leadership (Abanyam 2013; Ogo 2015; Ademiluka 2021; Ituma et al. 2021). Conversely,

Table 5 Distribution of household resilience capacity categories by household's socio-economic characteristics

Socio-economic variables	Low Resilience Category				High Resilience Category			
	ABC	ADC	TC	RC	ABC	ADC	TC	RC
Age (Years)	44.6	45.7	44.4	45.3	46.0	44.9	46.2	45.4
Sex								
Female	34 (37.0)	35 (38.0)	34 (37.0)	40 (43.0)	33 (36.3)	32 (35.2)	33 (36.3)	27 (30.0)
Male	58 (63.0)	57 (62.0)	58 (63.0)	53 (57.0)	58 (63.7)	59 (64.8)	58 (63.7)	63 (70.0)
Marital status								
Married	83 (90.2)	76 (82.6)	76 (82.6)	79 (84.9)	75 (82.4)	82 (90.1)	82 (90.1)	79 (87.8)
Divorced	1 (1.1)	0 (0.0)	1 (1.1)	1 (1.1)	0 (0.0)	1 (1.1)	0 (0.0)	0 (0.0)
Widowed	6 (6.5)	12 (13.0)	9 (9.8)	9 (9.7)	9 (9.9)	3 (3.3)	6 (6.6)	6 (6.7)
Single	2 (2.2)	4 (4.3)	6 (6.5)	4 (4.3)	7 (7.7)	5 (5.5)	3 (3.3)	5 (5.6)
Educational level								
None	24 (26.1)	27 (29.3)	30 (32.6)	32 (34.4)	29 (31.9)	26 (31.9)	23 (25.3)	21 (25.3)
Primary school	43 (46.7)	40 (43.5)	36 (39.1)	34 (36.6)	37 (40.7)	40 (40.7)	44 (48.4)	46 (48.4)
Secondary school	24 (26.1)	24 (26.1)	24 (26.1)	26 (28.0)	21 (23.1)	21 (23.1)	21 (23.1)	19 (23.1)
Tertiary	1 (1.1)	1 (1.1)	2 (2.2)	1 (1.1)	4 (4.4)	4 (4.4)	3 (3.3)	4 (3.3)
Household size (number)	8.0	8.4	8.1	8.2	9.0	9.2	9.5	9.4
Years spent in community (years)	29.5	28.0	27.7	27.3	28.1	29.6	29.9	30.3
Rice farming experience (years)	22.7	23.4	23.6	23.9	21.8	21.1	20.9	20.6
Volume of credit (Nigerian naira)	188,830.85	173,702.78	202,278.87	199,630.71	214,244.16	229,538.46	200,648.35	203,366.67
Farm size (ha)	2.7	2.7	2.4	2.7	2.5	2.5	2.7	2.5
Flood frequency								
Always	0.221	0.088	0.208	0.186	0.527	0.341	0.529	0.492
Seldom	0.272	0.083	0.246	0.211	0.492	0.287	0.488	0.399
Not at all	0.306	0.082	0.270	0.210	0.601	0.441	0.573	0.480
Drought frequency								
Always	0.304	0.119	0.226	0.257	0.509	0.324	0.535	0.405
Seldom	0.272	0.088	0.242	0.213	0.496	0.315	0.505	0.439
Not at all	0.243	0.080	0.236	0.192	0.522	0.302	0.499	0.418
Water insecurity prior five years								
Flood	0.282	0.094	0.226	0.239	0.584	0.469	0.541	0.493
Drought	0.241	0.083	0.239	0.194	0.496	0.284	0.474	0.406
Both	0.310	0.085	0.234	0.237	0.516	0.312	0.512	0.423
None	0.295	0.000	0.000	0.000	0.567	0.479	0.728	0.600
Index (Average score)	0.261	0.084	0.238	0.204	0.509	0.311	0.505	0.427
Frequency (Households in category)	92 (50.3)	92 (50.3)	92 (50.3)	93 (50.8)	91 (49.7)	91 (49.7)	91 (49.7)	90 (49.2)
Aggregate capacity index	0.384	0.197	0.371	0.314	0.384	0.197	0.371	0.314

Numbers in parenthesis are percentages. *ABC* = absorptive capacity, *ADC* = adaptive capacity, *TC* = transformative capacity, *RC* = resilience capacity

Source: Computed from field survey data (2021)

younger farmers exhibit higher adaptive capacity, likely due to their propensity to adopt innovations, participation in education and training, and greater engagement with social media, which facilitates access to information and networking. This generational difference in resilience strategies underscores the dynamic nature of adaptive capacity in the African context supporting the findings of Blackburn (2011), Läpple and Van Rensburg (2011), and Riverola et al. (2016).

Larger households, particularly those with support from social networks, demonstrate higher resilience, as access to additional labor and resources aids in coping with shocks. This is supported by findings from Bangura et al. (2013), Sanusi and Ayinde (2013), Ogunbo et al. (2015), and Hussain et al. (2020), who explained that larger households benefit from reliable sources of farm labour. Similarly, Mulwa et al. (2017) and Yiridomoh and Owusu (2021) highlight the importance of village kinship and social networks in

Table 6 Relationship between socio-economic characteristics and household resilience capacity

Variables	ABC	ADC	TC	RC
T-test Stat				
Age (Years)	42.814*** (0.000)	42.697*** (0.000)	42.834*** (0.000)	42.749*** (0.000)
Household size (number)	24.148*** (0.000)	24.148*** (0.000)	24.316*** (0.000)	24.255*** (0.000)
Years spent in community (years)	18.664*** (0.000)	18.641*** (0.000)	18.629*** (0.000)	18.626*** (0.000)
Rice farming experience (years)	20.748*** (0.000)	20.796*** (0.000)	20.804*** (0.000)	20.820*** (0.000)
Farm size (ha)	12.771*** (0.000)	12.771*** (0.000)	12.771*** (0.000)	12.771*** (0.000)
Volume of credit (Nigerian naira)	9.550*** (0.000)	9.565*** (0.000)	9.698*** (0.000)	9.597*** (0.000)
Chi-Square Stat				
Sex	0.009 (0.923)	0.163 (0.686)	0.009 (0.923)	3.336* (0.068)
Marital status	4.778 (0.189)	6.734* (0.081)	2.822 (0.420)	1.662 (0.645)
Education	2.916 (0.405)	2.013 (0.570)	2.119 (0.548)	6.925* (0.074)

ABC= absorptive capacity, *ADC*= adaptive capacity, *TC*= transformative capacity, *RC*= resilience capacity. Significance as follows: * ($\rho < 0.1$), ** ($\rho < 0.05$) and *** ($\rho < 0.01$)

Source: Computed from field survey data (2021)

adaptation strategies. In addition, access to credit significantly enhances resilience by enabling households to explore various adaptation strategies in response to climate change as noted by Simtowe and Zeller (2006), Shiferaw et al. (2014), Boansi et al. (2017), Mulwa et al. (2017) and Nzeyimana et al. (2021).

Interestingly, households with less rice farming experience and smaller farm sizes possess higher resilience. This finding suggests that younger, less experienced farmers, who are more inclined to adopt new techniques and adaptable to change, are better equipped to cope with weather-related shocks. In addition, smaller farm sizes may facilitate more manageable adaptation to shocks, although this contradicts the findings of Boansi et al. (2017) who argue that larger farm sizes enhance adaptive capacity. The adaptability of younger farmers and the smaller scale of operations could allow for more flexible responses to weather disruptions, as supported by Blackburn (2011), Läpple and Van Rensburg (2011), Riverola et al. (2016), and Ricart et al. (2022).

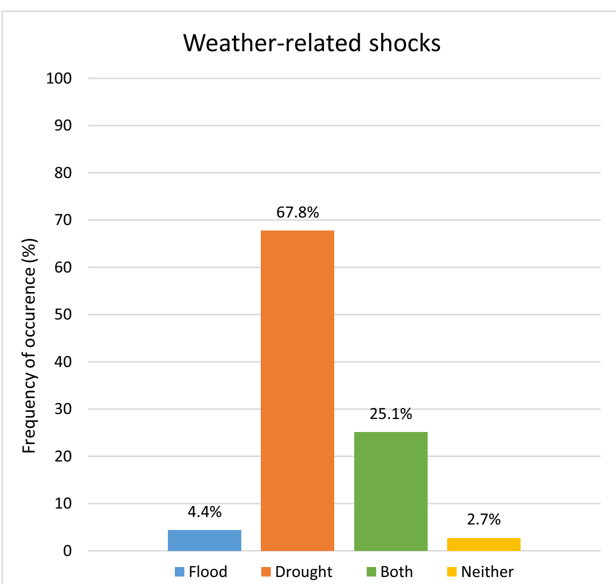

Fig. 3 Weather-related shocks experienced by rice farming households in the last 5 years. Source: Computed from field survey data (2021)

Finally, the prevalence of drought among households is linked with the low precipitation experienced in sub-Saharan Africa, with climate change and climate variability exacerbating water insecurity (Sims et al. 2021). Households that did not experience any weather-related shocks in the past 5 years demonstrate higher resilience. This is likely due to their ability to recover more effectively from previous shocks.

This study, contributes to the broader understanding of household resilience by demonstrating the importance of absorptive capacity and the influence of adaptive and transformative capacities in the context of water insecurity. While previous research does not specify which capacity is most vital for water insecurity, our findings indicate that absorptive capacity is the most critical, with key indicators, such as informal safety nets, bonding social capital, and shock preparedness playing a crucial role in enhancing the absorptive capacity of smallholder rice farming households. However, indicators like crop insurance schemes, use of irrigation, and construction of drainage systems, which have the potential to further strengthen household resilience, currently play a minimal role in strengthening absorptive capacity, hence

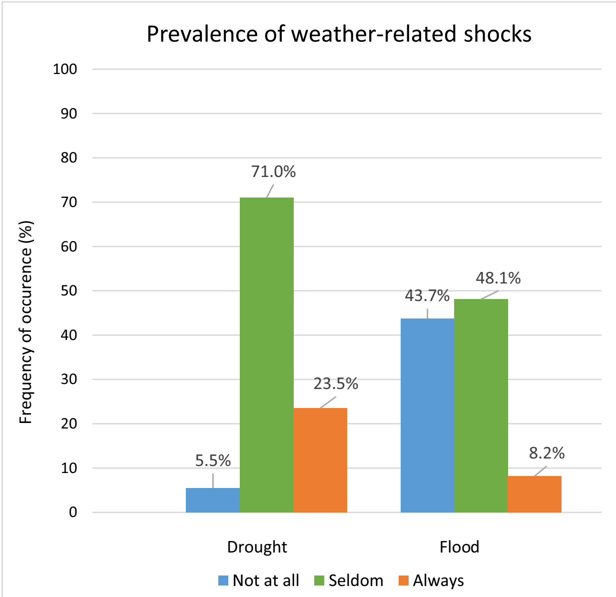

Fig. 4 Prevalence of weather-related shocks experienced by rice farming households in the last 12 months. Source: Computed from field survey data (2021)

the need for policy interventions that would further enhance the absorptive capacity of smallholder farming households' resilience in this regard.

Unlike previous methodologies for resilience measurement, such as the ordinary least squares (OLS) regression approach of Cisse and Barrett (2018), and the factor analysis employed by FAO (2016) and TANGO International (2018) in the area of food security, this research advances the discourse by employing TANGO International's (2018) categorical principal component analysis (CATPCA) with optimal scaling to derive absorptive, adaptive, and transformative capacities, providing a nuanced perspective on resilience indicators unique to water insecurity. By identifying gaps in the existing literature and highlighting the most crucial resilience capacity, the findings underscore the need for targeted policies and methodological advancements, making the study a significant contribution to resilience research.

Limitations of the research

The comparatively small sample size of this study, which is primarily composed of rice farmers from a particular geographic region, is an important drawback. The data used for this research is cross-section data. Collection occurred shortly after the outbreak of the COVID-19 pandemic thus hindering multiple visits to the study areas. Moreover, some of the study areas could not venture into rice production because of inadequate rainfall and partly due to the global COVID-19 pandemic. Although this limitation is acknowledged, it is important to take into account that similar contexts exist in various other areas where the results may be valid. In the future, this research can be expanded to the broader context of Nigeria and other sub-Saharan African countries. Furthermore, panel data analysis has generally been preferred in resilience studies, because it allows to capture variations in household responses to shocks, changes in wellbeing and resilience capacities over time (Wooldridge 2013).

The measurement of shocks and indicators of resilience capacities in this study are adapted from TANGO International's (2018) framework on resilience and food security. In contrast to The TANGO framework, this research focuses on weather-related shocks instead of shocks to food security which may have led to the omission of some relevant indicators in the conceptual framework. While a comprehensive set of relevant indicators for measuring resilience to water insecurity was identified based on the literature and the local context, they are not exhaustive and cannot be entirely disentangled from water insecurity. Our research, which pioneers the development of a resilience index based on water insecurity indicators, acknowledges inherent limitations and suggests that future research can explore more refined indicators to better capture the degrees of resilience to water insecurity.

The empirical tests presented in this paper confirm the existence of association between the overall resilience index and household water insecurity without investigating conduit mechanisms to food (in)security attainments; hence future research on relationships between water insecurity and food (in)security, the effects of water insecurity on household food (in)security and the different mechanisms through which household resilience capacity affects household water and food (in)security is needed in this area. Furthermore, using longer panel datasets of household surveys may be useful in deepening the analysis.

Conclusion

The aim of this research was to determine the resilience of smallholder rice farming households to water insecurity in Nigeria, with a case study in Ogun State. Agriculture in Nigeria is essentially rainfed. This makes smallholder rice farming households vulnerable to water insecurity caused by weather-related shocks. To reduce the negative effects of water insecurity and strengthen resilience, farmers can invest in agricultural water management techniques to limit the loss of access to water (e.g. rain harvesting) or limit the risk of flood damage (e.g. drainage). The research shows that farming households in

Table 7 Correlation between household resilience capacity dimensions and weather-related shocks

Resilience Dimension	RC	ABC	ADC	TC	Frequency (Drought)	Frequency (Flood)
RC	1.0000					
ABC	0.8517* (0.0000)	1.0000				
ADB	0.8973* (0.0000)	0.6800* (0.0000)	1.0000			
TC	0.8194* (0.0000)	0.5235* (0.0000)	0.6003* (0.0000)	1.0000		
Frequency (Drought)	−0.0320 (0.6668)	−0.1014 (0.1720)	0.0736 (0.3223)	−0.0669 (0.3684)	1.0000	
Frequency (Flood)	0.0593 (0.4248)	0.0538 (0.4698)	0.0838 (0.2591)	0.0133 (0.8587)	0.1156 (0.1193)	1.0000

The numbers in the table represent Pearson correlation coefficients; numbers in brackets are p-values; * denotes statistically significant correlations at the 0.05 significance level. ABC = absorptive capacity, ADC = adaptive capacity, TC = transformative capacity, RC = resilience capacity

Source: Computed from field survey data (2021)

Table 8 Analysis of variance (ANOVA) of household resilience capacity indexes for groups of households based on their exposure to weather-related shocks in the last five years

Resilience Variable		Sum of Squares	df	Mean Square	F
Absorptive Capacity Index	Between Groups	0.199	3	0.066	2.379*
	Within Groups	5.000	179	0.028	
	Total	5.200	182		
Adaptive Capacity Index	Between Groups	0.535	3	0.178	5.459***
	Within Groups	5.843	179	0.033	
	Total	6.378	182		
Transformative Capacity Index	Between Groups	0.945	3	0.315	13.026***
	Within Groups	4.328	179	0.024	
	Total	5.273	182		
Overall Resilience Capacity Index	Between Groups	0.620	3	0.207	8.075***
	Within Groups	4.579	179	0.026	
	Total	5.198	182		

Significance as follows:* ($\rho < 0.1$), ** ($\rho < 0.05$) and *** ($\rho < 0.01$)

Table 9 Multiple comparisons of household resilience capacity indexes for groups of households based on their exposure to weather-related shocks in the last five years

Resilience Variable	Weather-related shocks in the last five years (I)	Weather-related shocks in the last five years (J)	Mean Difference (I-J)
Absorptive Capacity Index	-	-	-
Adaptive Capacity Index	None	Drought	0.3055***
	None	Both	0.2660***
Transformative Capacity Index	Drought	Both	−0.0871***
	None	Flood	0.3058***
	None	Drought	0.3944***
	None	Both	0.3074***
Overall Resilience Capacity Index	Drought	Both	−0.0619**
	None	Flood	0.2020**
	None	Drought	0.3150***
	None	Both	0.2531***

A negative mean difference (I-J), means that the mean resilience index value for households exposed to weather-related shocks phenomenon I is lower than that of households exposed to shock J and vice versa. Only statistically significant relations were reported in this table. Significance as follows: * ($\rho < 0.1$), ** ($\rho < 0.05$) and *** ($\rho < 0.01$)

Source: Computation from field survey data (2021) the study area have a low level of resilience. It also reveals that the most important dimension contributing to household resilience is absorptive capacity while adaptive capacity contributes least to household resilience. Farmers are able to absorb shocks but their ability to adapt to shocks is low. It is therefore important to improve the capacities of farming households to become more structurally resilient in the long run.

Actions to stimulate resilience to water insecurity may include the use of irrigation on farm lands with improved facilities, such as small-scale agricultural water management systems at individual or community level. Also, implementing accessible crop insurance schemes, improving educational facilities, constructing roads for market access, and ensuring access to and availability of basic services are essential strategies to improve the resilience of farming households against shocks.

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Declarations

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