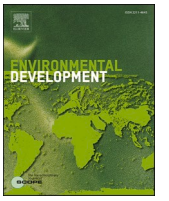
Environmental Development 51 (2024) 101040

Contents lists available at ScienceDirect

Environmental Development

journal homepage: www.elsevier.com/locate/envdev



Weather-related shocks, livelihood assets and coping strategies of water-insecure smallholder rice farmers: A case study from Ogun State, Nigeria

Muyinatu M. Sanusi [a,b,*], Liesbeth Dries [a]

[a] Wageningen University & Research, Wageningen School of Social Sciences, Agricultural Economics and Rural Policy Group, Hollandseweg 1, 6706 KN Wageningen, the Netherlands

[b] Federal University of Agriculture, Abeokuta, College of Agricultural Management and Rural Development, Department of Agricultural Economics and Farm Management, Abeokuta, P.M.B. 2240, Sapon, Ogun State, Nigeria

ARTICLE INFO

Keywords:
Extreme weather events
Household-level vulnerability
Sustainable livelihoods framework
Coping strategies index
Clustering

ABSTRACT

Building resilience against shocks is crucial for enhancing the livelihoods of water-insecure smallholder farming households. This research investigates household coping strategies for mitigating weather-related shocks and explores differences in the livelihoods of water-insecure smallholder rice farming households in Ogun State, Nigeria. Field survey data was collected from 175 households, and a coping strategies index was formulated, taking into account the severity and the frequency of coping measures. Using the k-means cluster approach, households were categorized into four clusters based on the components of the sustainable livelihoods framework. The study reveals variability across the clusters in terms of vulnerability and the degree to which households are able to use adequate coping strategies. Two out of the four clusters (clusters 1 and 2) are identified as coping farming households with moderate to high vulnerability to drought and floods, while clusters 3 and 4 are limited coping farming households with moderate to low vulnerability to these weather-related shocks. Addressing households' challenges to cope with extreme weather events is necessary to enhance the resilience and adaptability of water-insecure farming households, and will contribute to creating sustainable livelihoods of at-risk households facing climate emergencies.

1. Introduction

Exposure to weather-related shocks poses a threat to the successful cultivation of many types of crops and is one of the main causes of poverty in developing countries (Newman and Tarp, 2020). Weather shocks result in agricultural losses through poor harvests and crop failures with subsequent impacts on agricultural productivity, food security and rural livelihoods in affected areas (Krishnan and Dercon, 2000; Just and Pope, 2002; Mendelsohn, 2007; Headey, 2011; Nelson et al., 2014; Birthal et al., 2015; Kalkuhl et al., 2016; Baker et al., 2018; Berchoux et al., 2019; Chavas, 2019; Komarek et al., 2020; Ajah et al., 2022). The ability of households to adapt to the prevalence of such shocks and cope with their aftermath is an important determinant of welfare (Newman and Tarp, 2020).

Extreme weather events such as heat waves, droughts, floods, dry spells and cyclones are becoming more frequent, in occurrence,

* Corresponding author. Wageningen University & Research, Wageningen School of Social Sciences, Agricultural Economics and Rural Policy Group, Hollandseweg 1, 6706 KN Wageningen, the Netherlands.

E-mail addresses: muyinatu.sanusi@wur.nl, sanusimm@funaab.edu.ng (M.M. Sanusi), liesbeth.dries@wur.nl (L. Dries).

https://doi.org/10.1016/j.envdev.2024.101040
Received 12 December 2023; Received in revised form 3 July 2024; Accepted 15 July 2024
Available online 17 July 2024

intensity and magnitude; thereby threatening the sustainability of rural livelihoods (Nangoma, 2007; Ibrahim and Alex, 2009; Baker et al., 2018; Duru et al., 2022). These events are often worsened by developments such as deforestation or a combination of increasing population pressure, political tensions and economic changes that lead to practices causing environmental degradation (Pasteur, 2011; Matsa and Simphiwe, 2014; Hallegatte et al., 2016; Yadav et al., 2022).

Poor people often live in risk-prone areas such as on steep slopes, river embankments or floodplains which put their agricultural income at risk. Their livelihoods tend to be the hardest hit when disaster strikes and they need coping strategies to minimise risks and to survive, such as migrating to towns or other rural areas in search of employment, using credit from merchants and money lenders, or selling land, tools, equipment and other productive assets on which their livelihoods depend. This weakens their potential to recover and each shock can drive them deeper into poverty (Longhurst, 1986; Corbett, 1988; Montgomery, 1996; Pasteur, 2011). Available mechanisms to cope with weather-related shocks vary depending on individuals' or households' social standing and livelihood activities. In many rural settings, however, risk-mitigation strategies are difficult since credit and insurance markets are often not well developed (Cole et al., 2013; Linh et al., 2019; Ajah et al., 2022).

Existing research on climate and weather-related shocks in developing countries has concentrated on the implications of rainfall shocks for household food security and welfare, and household strategies for coping with famine in the face of shocks (Corbett, 1988; Ashraf and Routray, 2013; Akter and Basher, 2014; Ansah et al., 2021; Ansah, 2021; Boansi et al., 2021), agricultural investment decisions and shocks (Newman and Tarp, 2020; Leight, 2020), and climate shocks and social conflict (Fjelde and von Uexkull, 2012; Frankenberger et al., 2012; Hendrix and Salehyan, 2012; Papaioannou and de Haas, 2015). However, little is known about the mitigation of the effects of weather-related shocks by water-insecure rural farming households.

This research aims to investigate the coping strategies for mitigating various shocks of water-insecure smallholder rice farming households in Ogun State, Nigeria. Smallholder rice farming has an important role in achieving a sustainable livelihood and food and nutrition security in many developing countries, and Nigeria in particular. Rice is a staple food in Nigeria and the main source of agricultural income. Its production is dominated by smallholder farmers who are vulnerable to the risks of changing weather patterns, and land and environmental degradation (Awolala and Ajibefun, 2015; Vivek, 2019; Akanbi et al., 2022). Rising temperatures and changes in rainfall patterns have direct effects on crop yields and indirect effects through irrigation water availability, thus exacerbating the impacts of droughts, soil degradation and the decline in biodiversity (FAO, 2016).

First, the study offers a conceptual framework that links household livelihood assets and livelihood strategies of water-insecure farmers with the vulnerability context (i.e. climate variability, weather-related shocks and stresses) using the sustainable livelihoods framework (SLF). Next, it develops a coping strategies index at household level using a data set that was specifically collected to analyze shocks, livelihood assets and coping strategies. While previous studies have defined coping mechanisms in the context of household food security, the coping strategy index (CSI) in this study is developed specifically within the context of water insecurity. To this end, the index captures a variety of coping strategy indicators (reversible, erosive, and destitution mechanisms). This adds to the existing literature and provides future researchers with a useful methodological approach. Third, the factors that can influence household coping strategies, including socio-economic characteristics and SLF components, are investigated. Finally, the research applies cluster analysis and analysis of variance to group farming households based on the components of the sustainable livelihoods framework and to assess their potential to overcome water-related vulnerabilities.

The remainder of the paper is organised as follows. In the next section, the conceptual framework guiding the study is described. Section 3 lays out the methodology and the data used while section 4 presents the results. Section 5 discusses the results and section 6 concludes.

2. Conceptual framework

2.1. The sustainable livelihoods framework

The research is guided by the sustainable livelihoods framework (SLF), which shows the interactions between the factors affecting livelihoods. Introduced in 1987 by the World Commission on Environment and Development, the SLF helps improve the understanding of livelihoods, particularly those of the poor, by examining how people use their assets and capabilities to survive and improve their living conditions (WCED, 1987; DFID, 1999; Krantz, 2001; Kollmair and Gamper, 2002; Kanji et al., 2005). The framework depicts households as operating within a context of vulnerability, where access to assets is influenced by the social, institutional and organizational environment. This context shapes the livelihood strategies – ways of combining and using assets – that people use in meeting their livelihood objectives (Scoones, 1998, 2015; DFID, 1999; DFID, 2000; Kollmair and Gamper, 2002). The framework provides a comprehensive approach to understanding how people make a living and sees sustainable livelihoods as the capacity to cope with and recover from stresses and shocks, and to maintain or enhance capabilities and assets both now and in the future, while not undermining the natural resource base[1] (Chambers and Conway, 1992; DFID, 1999; Sen, 1999; Kanji et al., 2005; Gwimbi, 2009; FAO, 2011; Jaka and Shava, 2018; Natarajan et al., 2022).

Fig. 1 presents the five components of the SLF adapted from DFID (1999), highlighting the vulnerability context, livelihood assets, transforming structures and processes and livelihood strategies which support households in mitigating the effects of shocks on

[1] Natarajan et al. (2022) critique the SLF by Scoones (1998 & 2015) and DFID (1999) and reformulate it for the 21st century by addressing the limitations in theory, methodology, historical context, politics, and debates around decolonizing knowledge, incorporating elements such as climate change and globalization.

livelihood outcomes (Kanji et al., 2005). Agriculture is the main livelihood source for most rural dwellers in developing countries (Castaneda et al., 2018; Bello et al., 2021). In this research, vulnerability is defined as exposure to risks and shocks leading to water insecurity among water-insecure smallholder rice farmers (Chambers, 1989; Davies, 1996; Ellis, 1998). The weather-related shocks being faced by households include floods, droughts, soil erosion, water logging, pests and diseases (Thulstrup, 2015; Serrat, 2017). Livelihood assets are essential resources for livelihood strategies, including human, natural, physical, financial and social capital. Human capital captures the quality and quantity of labour, influenced by factors like household size, education, skill levels, leadership potential and health status. Natural capital includes resources such as land, forest and water. Physical capital comprises the basic infrastructure and tools needed to support livelihoods such as housing, equipment, roads and markets. Financial capital involves cash, savings, credit and income. Social capital captures social resources such as group memberships, social networks and connections (Scoones, 1998, 2015; DFID, 1999; Farrington et al., 2002; Serrat, 2017).

Transforming structures and processes are the institutions, organizations, policies and legislation that shape livelihoods. Example includes key initiatives for pooling resources and capacity-building activities aimed at enhancing smallholders' knowledge and skills (DFID, 1999; Maleksaeidi et al., 2016). Livelihood strategies are a range of activities undertaken to make a living, including short-term coping and long-term adaptive strategies such as crop intensification, water management techniques (rainwater harvesting, irrigation and drainage techniques) and migration (Davies, 1996; Scoones, 1998, 2015; Singh and Gilman, 1999; Farrington et al., 2002; Elasha et al., 2005; Chambers, 2009; Maleksaeidi et al., 2016; Serrat, 2017). Livelihood outcomes are the results of livelihood strategies and feed back into the vulnerability context and livelihood assets. Successful strategies allow households to build assets and reduce vulnerability, while poor outcomes deplete assets and increase vulnerability (DFID, 1999; Farrington et al., 2002; Bekele, 2022).

2.2. Shock exposure and coping strategies

Shocks can be defined as adverse events that can lead to a loss of household income, reduced consumption and/or loss of productive assets (Dercon et al., 2005). Exposure to shocks is determined by magnitude, frequency, and duration (Frankenberger et al., 2012). Shocks can be natural or man-made and vary in scale and duration. Based on scale, shocks are classified as covariate or idiosyncratic. Covariate shocks affect large populations in a geographic area, while idiosyncratic shocks affect specific individuals or households within a community. Regarding onset and duration, shocks are described as acute when they occur rapidly (rapid onset, typically short duration), or as chronic events when they occur over relatively long periods (slow onset, typically long duration). Weather-related shocks, like droughts (water scarcity) or floods (water surplus), refer to sudden or gradual natural covariate events caused by climate or weather conditions that disrupt livelihoods, particularly in agricultural settings, with intensity levels ranging from acute to chronic with direct impacts on water availability (Dercon et al., 2005; Frankenberger et al., 2012).

The coping strategy index (CSI) measures how households respond to shocks by employing various strategies to manage and mitigate their impact. It helps to quantify the extent to which households adjust their behaviours to cope with water insecurity and related challenges (Dercon et al., 2005; Maxwell and Caldwell, 2008; Frankenberger et al., 2012). Coping strategies are short-term measures that households use to manage and recover from adverse conditions, emergencies or disasters based on available skills and resources (Wisner et al., 2004; Pasteur, 2011; Haq et al., 2021). Chen et al. (2013) identify three types of coping strategies of farming households based on their reversibility: (i) *reversible mechanisms,* involve temporary shifts from cultivation to other activities which are observed when households take wage labour or sell protective assets such as jewellery); (ii) *erosive mechanisms*, usually implemented in response to heavy shocks undermining households' productive capacity like selling productive assets such as agricultural land; and (iii) *destitution,* occurs when households resort to permanent out-migration as a last resort. Coping strategies can be short-term or long-term strategies. Households are expected to prefer short-term, reversible strategies, such as the use of drought-tolerant crop varieties, over more severe, irreversible strategies with long-term effects, such as drainage canal constructions. In extreme cases, climate shocks can lead to the collapse of coping mechanisms and the loss of livelihoods, prompting migration and destitution (Maxwell and Caldwell, 2008; WFP, 2009; FAO, IFAD, Unicef, WFP and WHO, 2018).

3. Materials and methods

3.1. Study area

The study was conducted in Ogun State of Nigeria's Southwest geo-political zone. This zone consists of 20 local government areas and covers 16,762 square kilometres of land with 80% being arable (NBS, 2019a, 2019b; Igwenagu, 2021; Nigeria Galleria, 2021; WPR, 2022). Geographically, it is situated between latitude 6.2°N and 7.8°N and longitude 3.0°E and 5.0°E. Ogun State's climate follows a tropical pattern with a dry season from November until March and a rainy season from April to October. The mean annual rainfall distribution varies from 128 mm in the southern parts to 105 mm in the northern areas. Relative humidity ranges between 76% and 95%, coinciding with the dry and wet seasons, respectively. The temperature ranges from a monthly mean of 23 °C in July to 32 °C in February. The State's vegetation comprises savanna in the northern part to rainforest features in the central parts and coastal towns

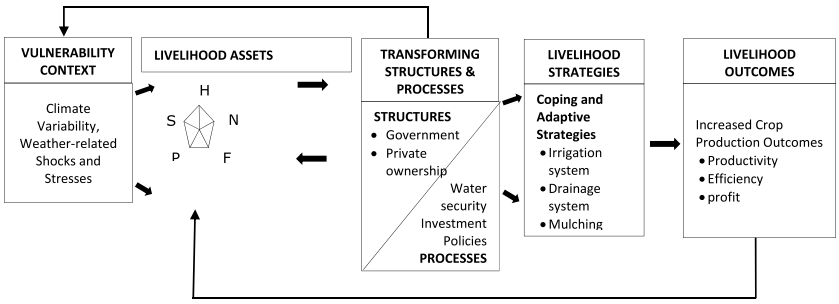


Fig. 1. Sustainable livelihoods framework of water-insecure smallholder rice farmers, adapted from the Department for International Development of the United Kingdom (DFID, 1999).
Note: The meaning of the alphabets; H = Human capital, N = Natural capital, F = Financial capital, P = Physical capital and S = Social capital.

with the southern landscape consisting of mangrove swamps. Ogun State has a vast network of water bodies (rivers and streams) that provides good potential for fishing activities, crop production, and fadama[2]agriculture, but also suffers from frequent occurrences of droughts and floods. The study was carried out specifically within the agricultural zones of Abeokuta and Ikenne, chosen for their distinct characteristics and predominantly rural setting. The primary occupation of the people is agriculture and the major food crops grown in the State are rice, maize, cassava, yam, cocoyam, and banana while cash crops include cocoa, kola nut, rubber and oil palm (NBS, 2019a, 2019b; Igwenagu, 2021; Nigeria Galleria, 2021; WPR, 2022). The types of rice grown in the study area include upland, lowland and fadama rice (Akinwumi, 2013). Ogun State is divided by the Ogun State Agricultural Development Programme (OGADEP) into Abeokuta, Ikenne, Ilaro and Ijebu-Ode agricultural zones which are further divided into blocks. The blocks are further subdivided into cells, each of which contains a number of farming communities (see Fig. 2).

3.2. Data collection

Cross-sectional data were obtained through an open data kit in the 2020/2021 agricultural season from 183 rice farming households in Ogun State, Nigeria. The study's sampling procedure was based on the structure of the Ogun State Agricultural Development Programme (OGADEP) with the stratification of the state into agricultural zones, blocks and cells (OGADEP, 2005). Cells comprise of a cluster of villages. A cross-sectional survey involving a multi-stage sampling of 200 rice smallholders was adopted. In the first stage, Abeokuta and Ikenne agricultural zones were purposively selected based on rice production intensity. The second stage entailed a purposive selection of 1 block per selected zone (Wasimi and Obafemi-Owode) and 1 cell per selected block (Wasimi and Mokoloki) in the third stage. Finally, in the fourth stage, 100 rice smallholder farming households were selected by random sampling across each selected cell using OGADEP's list of rice smallholders as the sampling frame. After excluding households with incomplete information, 175 households were retained in the study. Data obtained include smallholder households' socio-demographic, farm-level characteristics, identification of the various shocks being experienced, coping strategies used and available assets.

3.3. Methods for analysis

The study aims to assess the differences in sustainable livelihoods and coping strategies of water-insecure smallholder rice farming households. To this end, the Coping Strategies Index (CSI) is adjusted to the case of water insecurity arising from weather-related shocks. The CSI was developed to measure household food insecurity; monitor changes which take place in emergency situations; assess the impact of programmes and interventions; and also as a food insecurity early warning indicator (Maxwell, 1996; Maxwell et al., 1999, 2003; Maxwell and Caldwell, 2008). The CSI measures behaviour and the things that people do when they cannot access enough sustenance. It can be adapted to other applications. For this study, the CSI is described as a measure of strategies used by farming households to mitigate weather-related effects of shocks and was calculated by using a specific set of coping behaviours based on questions about how households cope with weather-related shocks and stresses (Maleksaeidi et al., 2016; TANGO International, 2018). Following Maxwell and Caldwell (2008), the CSI comprises the frequency of these coping behaviours (how often is the coping strategy used?) and the severity of the strategies (to what degree are these strategies reversible?).

3.3.1. Constructing the coping strategies index

Step 1. Frequency: counting the frequency of strategies

To determine the CSI for the study, households were asked about the measures they considered in response to, to recover from or to

[2] Fadama refers to irrigable land in Nigeria's river systems: flood plains and low-lying areas with shallow aquifers. These areas are seasonally flooded and suitable for farming during the dry season. Fadama, also known as wetlands when spread over a larger area, have significant potential for economic development through investments in infrastructure, household assets, and technical assistance. They are waterlogged during the rainy season but retain moisture in the dry season.

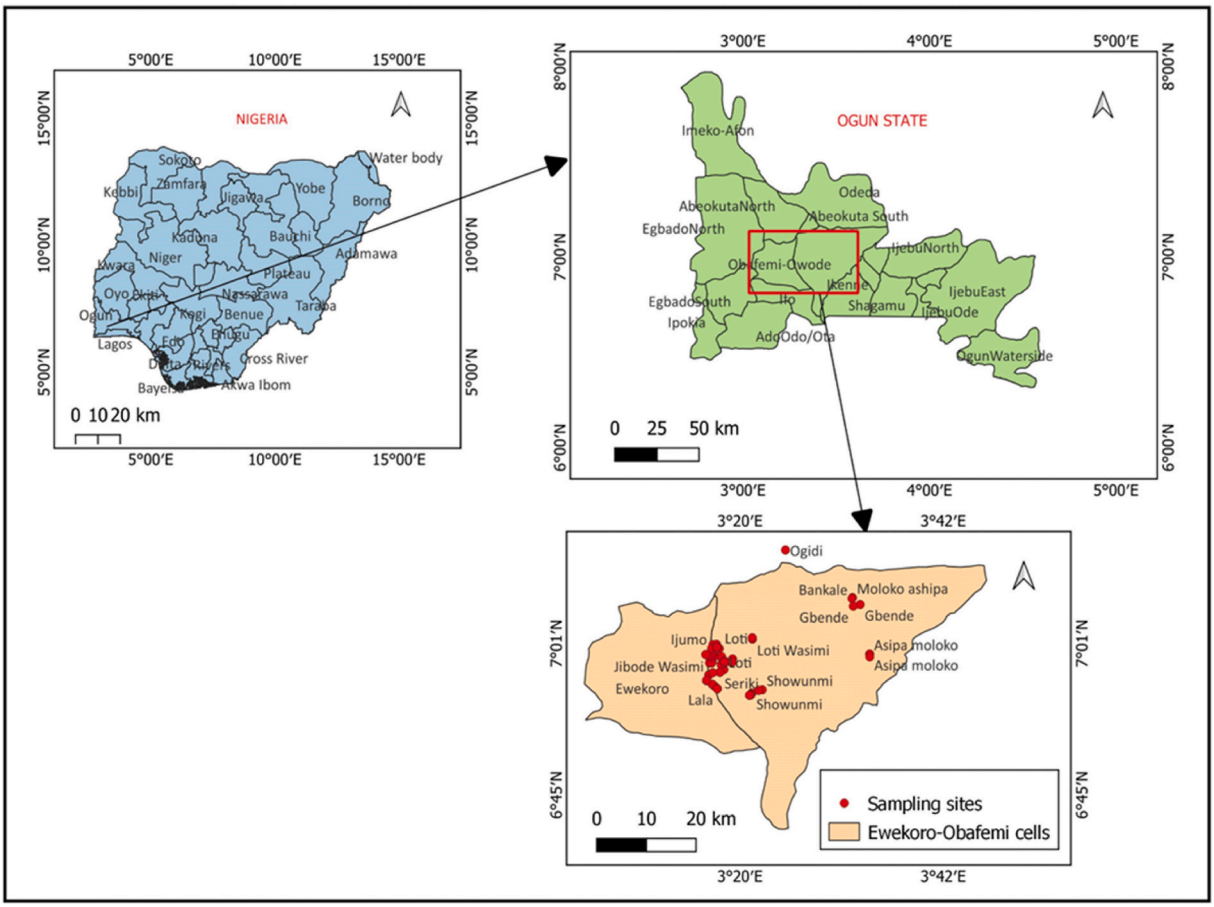


Fig. 2. Map of Nigeria showing Ogun State and the location of the study sites.
Source: Drawn with QGIS using study location GIS, the country boundary shape file of Nigeria was downloaded from https://www.diva-gis.org/gdata

withstand weather-related shocks whenever they are faced with them. A list of coping strategies is reported in Appendix 1. The relative frequencies for the coping strategies were scored to represent the number of times a household had to rely on each coping behaviour in the production season. This score ranges from "Always = 3", "Seldom = 2", and "Not at all = 1".

Step 2. Severity: categorizing and weighting the strategies

Household coping strategies are not always equal in severity, thus different strategies are "weighted" differently, depending on how severe they are for the households that rely on them. Three severity categories were considered based on their degree of reversibility: reversible mechanisms (the least severe category of individual behaviours), erosive mechanisms (the moderately severe category), and destitution mechanisms (the most severe category). A severity weighting of 1, 2 and 3 was assigned to each severity category with the lowest weight attached to the least severe category (see Appendix 1).

Step 3. Combining frequency and severity

The CSI was calculated by summing the weighted scores (the product of the frequency score of each coping strategy and the corresponding severity weight per strategy) for all strategies per household (Maxwell et al., 1999; Maxwell and Caldwell, 2008). The CSI for the jth household is specified in equation (1):

$$CSI_j = \sum_{t=1}^{s} F_{tj} W_{tj} \tag{1}$$

Where, CSI_j is the coping strategy index of the jth household in the study ($j = 1, 2, \ldots\ldots, 175$)

F_{tj} is the frequency score for each strategy t that is adopted by the jth household, with $t = 1,2, \ldots s$, and s being the total number of strategies. W_{tj} is the severity weight assigned to each strategy t adopted by the jth household.

Step 4. Interpretation of the Coping Strategies Index

High CSI scores indicate that limited coping strategies are available to households, and lower scores indicate sufficient coping

strategies. It should be noted that because of the combination of frequency and severity in the index, it is possible that two households with the same CSI score are using different strategies where one household could be employing multiple strategies at a relatively low frequency while the other household could be employing fewer but more severe coping strategies. However, research has shown that households will tend to employ the less severe (and more reversible) strategies first before they adopt more severe (and less reversible) strategies (Maxwell and Caldwell, 2008; FAO, IFAD, Unicef, WFP, WHO, 2018).

3.3.2. Coping strategies and household characteristics

To investigate the relationship between household coping strategies, socio-economic status and livelihood assets, all households are assigned to a category based on the coping strategies index. Two categories of households are created by taking the median of the distribution of the coping strategies index as a cut-off value. Below the cut-off value, households are categorized as having adequate coping strategies while above this value, they are categorized as having inadequate coping strategies. Statistical analyses including t-tests and chi-square statistics are employed to examine significant differences in specific characteristics between the two categories using household socio-economic status and SLF components.

3.3.3. Identifying the potential of households to overcome water-related vulnerabilities through cluster analysis

Cluster analysis is a classification procedure to explore data sets in terms of internal cohesion (homogeneity) and external isolation (separation) (Cormack, 1971; Gordon, 1999; Han and Kamber, 2006; Kettenring, 2006; Hair et al., 2010, 2019; Everitt and Hothorn, 2011; Everitt et al., 2011; Han et al., 2012). It i s a widely used method that helps decision-makers to decide how to increase effectiveness and efficiency with the available resources (Bezlepkina, 2004). It is also used to trace out the dynamics in progress in agricultural and rural development (Mazzocchi and Montresor, 2000; Everitt and Hothorn, 2011; Everitt et al., 2011).

The potential to overcome water-related vulnerabilities, or the resilience, of water-insecure households is affected by a variety of factors (see Fig. 1). Cluster analysis allows to categorize households based on the determinants in the SLF[3]. Hence, the study adopts a deductive approach in selecting the clustering variables that were included in the estimation of the cluster solution (Ketchen et al., 1993; Ketchen and Shook, 1996). The description of the variables used in the k-means clustering technique (an iterative or partitioning method and one of the most common methods in non-hierarchical cluster analysis) is given in Table 1. All variables were standardized such that the distance between groups along all clustering variables is maximized. Variables with large ranges (i.e., where elements are separated by large distances) are given more weight in defining a cluster solution than those with small ranges (Hair et al., 1992). As a result, a subset of variables can dominate the definition of clusters. Standardisation allows similarity or equal weighting among scales of the input variables to avoid problems associated with the different units in which the variables of interest were obtained (Milligan and Cooper, 1988). The standardized values for all the clustering variables were estimated using equation (2):

$$Z_i = \frac{X_i - \mu_i}{\sigma_i} \tag{2}$$

where Z_i is the z-score of the ith household; X_i is the value for a specific variable used in the cluster analysis of the ith household, μ_i and σ_i is the mean and standard deviation for a specific variable for the sampled households, respectively.

3.3.4. Analysis of variance (ANOVA)

The One-way ANOVA procedure determines the significant level of the clustering variables that contributed more to the cluster membership formation. This allows testing the hypothesis that rural farming households differ in some specific characteristics (vulnerability context, livelihood capitals and livelihood strategies) which in turn affect the sustainability status of the households. The Fisher's Least Significant Difference (LSD) test for equal variances (Fisher, 1935) was performed with version 28.1 of SPSS software to find the significance of differences between paired groups (see Appendix 3for details).

4. Results

4.1. Coping strategies used by surveyed households

Rice farming households adopt several strategies which help them to cope and mitigate shocks whenever they arise. Table 2 reports the elements of the coping strategies index (CSI) for smallholder households. The indicators of reversible mechanisms (the least severe strategies) show that the adding of new crops/changing crop species and the use of drought tolerant/resistance crop varieties/seeds are the least used strategies while using a diverse workforce is the most frequently used strategy. The indicators of erosive mechanisms show that pest and disease control; soil and erosion control; and rainwater harvesting techniques, storage and conservation are the most used strategies while the collection of run-offs from floods was the least used strategy. The indicators of destitution mechanisms show that seeking off-farm employment and the suspension of farming activities on the flooded farmland were the least used strategies while migration to other areas and seeking assistance from various organizations were the most used strategies.

[3] The transforming structures and processes in the livelihoods framework for this study only captured data for one region where the institutions and policies are the same. Therefore, this element of the SLF was not considered within the scope of this study. Harvesting (production) was still ongoing during the period of data collection; therefore, it was excluded from the livelihood outcomes component of the SLF.

Table 1
Summary statistics of the variables present in the SLF.

SLF components	Indicator variables	Measurements	Min.	Max.	Mean	Std. dev.
Vulnerability Context (VC)	Drought	If the household experienced the occurrence of drought during the growing season Never = 0 Once = 1 Twice = 2 Thrice = 3 More than 3 times = 4	1	5	3.16	1.12
	Flood	If the household experienced the occurrence of flood during the growing season Never = 0 Once = 1 Twice = 2 Thrice = 3 More than 3 times = 4	1	5	2.25	1.32
Livelihood Assets (LA)						
Human Capital	Sex	2 if male, 1 if female	1	2	1.65	0.48
	Age	Years	16.00	74.00	45.55	14.26
	Household size	Number of household members excluding children	1.00	15.00	8.45	3.81
	Education status	2 if formal education, 1 otherwise	1	2	1.71	0.46
	Rice farming experience	Years	1.00	45.00	21.42	13.44
Natural Capital	Soil type/quality	Very poor = 1 Poor = 2 Fair = 3 Good = 4 Very good = 5	1	5	4.01	0.57
	Water sources	Number of water sources available to the household (1–8; Bore-hole, Deep-well, River, Pond, Lake/ streams, Harvested Rainwater, Public Water Company, Water Vendor)	1.00	4.00	1.27	0.57
	Farm size	Hectare (ha)	0.20	4.00	2.19	1.07
	Trees on land	2 = Yes if present, 1 otherwise	1	2	1.73	0.44
Physical Capital	Productive Assets Owned	Number of productive assets owned by the household (1–8; Hoe, Cutlass, Knapsack sprayer, Bowls, Baskets, Gloves, Tractor, Others)	2.00	8.00	5.50	1.512
Financial Capital	Credit Sources	Number of Credit Sources available to the household (1–7; Family, Friend, Esusu/Ajo/Aro, Money Lender, Formal Institution, Personal, Others)	1.00	2.00	1.26	0.44
	Volume of Credit	Nigerian Naira (N)	10000.00	400000.00	177518.03	116124.41
Social Capital	Membership of community-based organizations	Yes = 2 No = 1	1	2	1.61	0.49
Livelihood Strategies (LS)	Coping strategy	CSI	40.00	63.00	49.67	7.01

Source: Field survey (2021)

4.2. Analysis of household coping strategies in relation to socio-economic characteristics and livelihood assets

Table 3 shows the socio-economic characteristics, livelihood assets and coping strategies of households with adequate and inadequate coping strategies. The results show that 69 farming households have inadequate reversible coping strategies, 82 have inadequate erosive coping strategies, 86 have inadequate destitution coping strategies and 82 have inadequate overall coping strategies. Significant differences are found for the adequacy of destitution coping strategies and gender, erosive coping strategies and rice farming experience, and reversible coping strategies and membership of community-based organization participation of rice farming households. A significantly negative association is found between destitution coping strategies and farm size; and between the adequacy of reversible, erosive and overall coping strategies and credit sources of the farming households.

4.3. Typologies of farming households based on the SLF components

The analysis identifies four distinct farming household groups differentiated by the components of the SLF (vulnerability context, livelihood assets, and livelihood strategies). Thirteen out of the 16 variables significantly contribute to and provide a good level of separation between the various clusters while the variables of educational status, farm size and number of productive assets owned give no separation between clusters and did not contribute to the cluster group formation (see Appendix 2). Table 4 is a summary of the results of the ANOVA analysis (Appendix 3). It reports the profile of the four clusters. The clusters are ordered based on their level of vulnerability to weather-related shocks and the use of coping strategies.

Table 2
Elements of the coping strategies index for smallholder households.

Indicators	Mean score[a]
Reversible mechanisms	
Strategies related to changing farming practices	
Adding new crops/changing crop species	1.23
Use of drought tolerant/resistance crop varieties/seeds	1.24
Sustainable land management practices	1.33
Change the timing of crop planting	1.35
General strategies related to overcoming weather-related shocks	
Relying on assistance from relatives and friends	1.63
Membership in community-based organizations	1.63
Using diverse workforce	1.74
Sharing of resources and technology within the community	1.43
Erosive mechanisms	
Mechanisms for controlling water sources	
Rainwater harvesting techniques, storage and conservation	2.56
Use of irrigation	2.17
Constructing flood dykes, control levees, flood retention areas, groynes, drainage canals, embankment/dam, river embankments	2.15
Collection of run-offs from flood	1.03
Mechanisms to minimise production losses	
Soil and erosion control	2.71
Pest and disease control (indirect effects of weather-related shocks)	3.45
Managerial mechanisms to minimise production losses and weather-related shocks	
Can access funds for dealing with short-term disasters	2.24
Can access insurance coverage for major (private) assets	2.07
Participates in risk and vulnerability planning	2.29
Prepares and trains for short-term changes	2.41
Prepares and trains for long-term changes	2.23
Destitution	
Seek assistance from various organizations	3.53
Stopped farming the land that was flooded	1.65
Relocating to higher grounds, non-drought or unflooded area	3.39
Migration (to urban or other rural areas)	3.43
Livelihood diversification (e.g. Sought off-farm employment)	1.44

Mean score[a] = average overall households of frequency x severity per each coping strategy Source: Field survey data (2021)

Cluster 1: Moderate vulnerability but coping households.

This cluster represents the largest portion of the total sample (54.9%, 96 farming households). In terms of vulnerability, these households are susceptible to drought but less vulnerable to floods. The cluster exhibits relatively high levels of human capital, characterized predominantly by males, constituting mostly youths with an average age of 38 years and formal education. They also possess relatively high natural capital including fertile soil quality and large farm sizes. In terms of physical capital, they have more assets, but they have low credit sources with least volume of credit indicating a lower financial capital. In addition, they are not associated with any community-based organizations, indicating no social capital. Vulnerability due to shocks can be mitigated by the use of coping strategies. This cluster demonstrates the highest level of coping strategies among all the clusters, with a coping strategy index (CSI) of 48.3 indicating sufficient coping strategies to counter weather-related shocks.

Cluster 2: High vulnerability but coping households.

This cluster represents 35.4% of the total sample and consists of 62 farming households. The vulnerability context reveals a high susceptibility to weather-related shocks, both drought and floods. The cluster possesses relatively high human capital, as indicated by the extensive experience in rice farming, the level of formal education and the number of individuals in the household. The mean age of household heads is 54 years and they are primarily male-dominated and elderly. The cluster also exhibits relatively high natural capital including good soil quality and large farm sizes. However, this group has low physical capital. In terms of financial capital, this cluster has the highest volume of credit among all the clusters. Furthermore, the farming households in this cluster are members of community-based organizations, indicating the presence of social capital. This cluster has access to sufficient coping strategies with a CSI value of 49.6.

Cluster 3: Households with moderate vulnerability and limited coping strategies.

This is the smallest cluster, representing 1.7% of the total sample with only 3 farming households. The vulnerability context shows that households in this cluster are not susceptible to drought but more vulnerable to floods. The livelihood capitals show that human capital are characterized predominantly by elderly females, with an average age of 51 years, small household sizes, and a lack of formal education. Despite significant years of experience in rice farming, they have the lowest natural capital including poor soil quality, low water sources and small farm sizes. They have a higher number of physical assets but relatively low financial capital, as evidenced by low credit sources and volumes. Furthermore, they are not affiliated with any community-based organizations, indicating a lack of social capital. This cluster exhibits a low level of coping strategies with a coping strategy index (CSI) of 56.0 suggesting that households face more constraints in adopting strategies to cope with weather-related shocks.

Cluster 4: Households with low vulnerability and limited coping strategies.

Table 3
Household coping strategies, socio-economic characteristics and SLF components.

SLF/socio-economic characteristics	Inadequate coping strategies	Adequate coping strategies	Sig.	Inadequate coping strategies	Adequate coping strategies	Sig.	Inadequate coping strategies	Adequate coping strategies	Sig.	Inadequate coping strategies	Adequate coping strategies	Sig.
	RCSI	RCSI		ECSI	ECSI		DCSI	DCSI		CSI	CSI	
Livelihood Assets (LA)												
Human Capital												
Sex												
Female	23 (33.3)	39 (36.8)		24 (29.3)	38 (40.9)		23 (26.7)	39 (43.8)	**	26 (31.7)	36 (38.7)	
Male	46 (66.7)	67 (63.2)		58 (70.7)	55 (59.1)		63 (73.3)	50 (56.2)		56 (68.3)	57 (61.3)	
Age (Years)	47.7	44.2		45.3	45.7		45.8	45.4		46.5	44.7	
Household size (number)	9.0	8.0		8.0	8.0		9.0	8.0		9.0	8.0	
Educational status												
Formal	49 (71.0)	75 (70.8)		60 (73.2)	64 (68.8)		63 (73.3)	61 (68.5)		56 (68.3)	68 (73.1)	
Informal	20 (29.0)	31 (29.2)		22 (26.8)	29 (31.2)		23 (26.7)	28(31.5)		26 (31.7)	25 (26.9)	
Rice farming experience (years)	22.8	20.5		19.1	23.5	**	20.5	22.3		21.0	21.8	
Natural Capital												
Farm size (ha)	2.2	2.2		2.3	2.1		2.3	2.0	**	2.3	2.1	
Financial Capital												
Credit sources	1.4	1.2	**	1.4	1.2	**	1.4	1.2		1.4	1.2	**
Volume of credit (Nigerian Naira)	178,090	177,145		190,261	166,281		187,569	167,805		184,917	170,994	
Social Capital												
Membership of community-based organizations												
Yes	50 (72.5)	56 (52.8)	**	51 (62.2)	55 (59.1)		53 (61.6)	53 (59.5)		54 (65.9)	52 (55.9)	
No	19 (27.5)	50 (47.2)		31 (37.8)	38 (40.9)		33 (38.4)	36 (40.5)		28 (34.2)	41 (44.1)	

NB: Numbers in parenthesis are percentages. significance: * ($\rho < 0.1$), ** ($\rho < 0.05$) and *** ($\rho < 0.01$).
Reversible coping strategies = RCSI; Erosive coping strategies = ECSI; Destitution coping strategies = DCSI; Overall coping strategies = CSI.

Table 4
Farming households cluster groups.

S/N	Indicators	Cluster 1: Households with Moderate vulnerability but coping	Cluster 2: High vulnerability but coping	Cluster 3: Moderate vulnerability but limited coping strategies	Cluster 4: Low vulnerability and limited coping strategies
Vulnerability Context					
1	Vulnerability to drought	Highly vulnerable (Twice)	Highly vulnerable (Twice)	Low vulnerable (Not at all)	Low vulnerability (Once)
2	Vulnerability to flood	Low vulnerability (Once)	Highly vulnerable (Twice)	Highly vulnerable (Several times)	Low vulnerability (Once)
Livelihood Assets					
Human Capital					
3	Sex	Male-dominated	Male-dominated	Female-dominated	Female-dominated
4	Age (years)	Youths (38 years)	Elderly (54 years)	Elderly (51 years)	Elderly (53years)
5	Household size (number)	Low household size (7 persons)	More household size (11 persons)	Low household size (7 persons)	More household size (11 persons)
6	Educational status	Formal education	Formal education	Informal education	Formal education
7	Rice Farming Experience (years)	Low years of experience in rice farming (15 years)	More years of experience in rice farming (32 years)	Moderate years of experience in rice farming (21 years)	Moderate years of experience in rice farming (21 years)
Natural Capital					
8	Soil type/quality	Good soil quality	Good soil quality	Poor soil quality	Good soil quality
9	Number of water sources (number)	Low (1 sources)	Low (1 source)	Low (1 source)	More (3 source)
10	Farm size (ha)	Large (2.1 ha)	Large (2.4 ha)	Small (1.3ha)	Medium (1.9ha)
11	Trees on land (Yes/No)	Presence	Presence	Absence	Presence
Physical Capital					
12	Number of productive assets owned (number)	More assets (6)	Low assets (5)	More assets (6)	More assets (6)
Financial Capital					
13	Number of credit sources (number)	Low (1 sources)	Low (1 source)	Low (1 source)	More (2 sources)
14	Credit volume (N)[a]	Low volume of credit (N148,741)	More volume of credit (N226,716)	Moderate volume of credit (N183,333)	Low volume of credit (N155,714)
Social Capital					
15	Membership of community-based organizations	No	Yes	No	Yes
Livelihood Strategies					
16	CSI	Low CSI (48.3)	Low CSI (49.6)	High CSI (56.0)	High CSI (58.1)

K-Means Cluster Analysis results (four-cluster solution). Numbers and/or words in parentheses specify the means of each variable for the specific cluster group.

[a] In the survey year 2021, one Euro equals N454.55 Nigerian Naira.

This cluster accounts for 8.0% of the total sample with 14 farming households. In terms of vulnerability context, these households exhibit the lowest vulnerability to weather-related shocks, such as drought and flood, compared to other clusters. The cluster possesses high human capital characterized by more years of experience in rice farming, formal education and larger household sizes with the mean age of the household heads being 53 years. They also have relatively high natural capital, including good soil quality, multiple water sources and medium-sized farms. In terms of physical capital, they have more productive assets. Surprisingly, despite having more credit sources, they have the low volume of credit, indicating a low financial capital. They are active members of community-based organizations, indicating the presence of social capital. This cluster exhibits the lowest level of coping strategies, with a CSI value of 58.1, suggesting that they employ the lowest range of coping mechanisms to deal with weather-related shocks. This may not be surprising, however, because their low level of vulnerability makes them the least in need of coping strategies.

5. Discussion

5.1. Coping strategies, socio-economic characteristics and SLF components

The results show a connection between specific characteristics of farming households and the adequacy of various coping strategies. The positive association between gender and destitution coping strategies is an indication that male-led households are better at employing adequate destitution coping strategies. This aligns with the findings by Kabeer (2005), and Ayana et al. (2021) who emphasize the importance of considering gender in the development and implementation of coping strategies. The negative association between farm size and the adequacy of destitution coping strategies indicates that smaller farms may be more agile and capable of implementing efficient destitution coping strategies. Their smaller scale may allow for faster decision-making, more direct management, and potentially stronger community ties, all of which can contribute to more effective coping mechanisms. Larger farms often face more complex challenges which include resource allocation, labour management, and vulnerabilities to weather-related shocks. This finding aligns with previous studies that highlight the significance of farm size on the ability of farming households to manage

destitution coping strategies (Kassie et al., 2015; Adjognon et al., 2017).

5.2. Interrelationships between vulnerability context, livelihood capitals and coping strategies in smallholder rice farming households

Smallholder rice farming households differ in terms of vulnerability to weather-related shocks, livelihood assets and coping strategies to mitigate shocks which in turn influence their production outcomes (Tesliuc and Lindert, 2002; Arouri et al., 2015; Chamdimba et al., 2020). Sustainable livelihoods of farming households are crucial to build resilience to shocks and to increase agricultural production (Alinovi et al., 2010; Udoh et al., 2017; Nasrnia and Ashktorab, 2021). This research assessed the coping strategies for mitigating various weather-related shocks and identified differences in the livelihoods of water-insecure smallholder rice farming households. The findings from the cluster analysis show a diversity among farming households regarding the factors that shape their potential for achieving sustainable livelihoods within the study area.

First, the large majority of households exhibit a certain level of vulnerability. Households face challenges in adapting to climate variability and change. However, they mitigate the effects by adopting strategies which can contribute to sustainable income generation. The findings from this research align with the research by Keshavarz and Moqadas (2021), who suggested that households employing coping and adaptation strategies to address climatic extremes could attain higher levels of resilience. Clusters 1 and 2 comprise vulnerable but coping farming households. They are male-dominated and have formal education. These clusters have a potential advantage in human capital in terms of knowledge and skills that can be leveraged for agricultural innovation, adoption of improved farming practices, and capacity-building initiatives. They have large farm sizes with good soil quality indicating a favourable environment for agricultural activities and this can contribute to agricultural productivity, diversification opportunities and sustainable livelihoods. Previous research hypothesized that male-headed households are more likely to have better opportunities to practice adaptation measures because men do much of the agricultural work, have the ability to access resources and new technologies and have the willingness to undertake greater risks than women (e.g., Asfaw and Admassie, 2004; Deressa et al., 2009; Demetriades and Esplen, 2008; Nyberg et al., 2021).

On the other hand, cluster 3 comprises farming households with limited coping strategies. The population in this group is ageing rapidly, lacks formal education and may pose a potential future challenge in terms of succession planning and intergenerational knowledge transfer within the farming community. The effectiveness of coping strategies and decision-making depends to a large extent on external support mechanisms, institutional frameworks, and broader socio-economic context in which these households operate thereby contributing to resilience and adaptive capacity in farming communities. Earlier research has found that women have different vulnerabilities compared to men, and that they face social, economic and political barriers which limit their resilience capacities (Doss and Morris, 2000; Maddison, 2007; Nhemachena and Hassan, 2007; Silvestri et al., 2012; Jaka and Shava, 2018; Aijazi et al., 2021).

Furthermore, the vast majority of households have low financial capital. This suggests that farming households face challenges in accessing financial resources and may restrict their capacity for investments or expansion. This result is in line with the finding that access to financial resources facilitates the mitigation of the adverse effects of shocks on households' welfare (Sawada, 2006; Arouri et al., 2015). Enhancing access to financial services and promoting financial inclusion could further support agricultural activities, improve livelihoods, and enable investment in productive assets as recommended by Carleton and Hsiang (2016), Hallegatte and Rozenberg (2017), Yegbemey et al. (2017) and Brown et al. (2018).

Farming households in clusters 1 and 3 are not involved in community-based organizations, indicating the absence of social capital. A social network can provide opportunities for collective action, knowledge sharing, and access to resources beyond individual capacities. Strengthening social capital through cooperative initiatives, farmer groups, or knowledge exchange platforms can promote collaboration, learning, and advocacy for specific needs as suggested by Yegbemey et al. (2017). Further support to enhance access to safety nets could improve households' adaptive capacity and reduce vulnerability. Understanding these implications can inform targeted interventions and policy measures to enhance household resilience, productivity, and overall well-being as highlighted by Kassie et al. (2013), Teklewold et al., 2013 and Akpan et al. (2016).

5.3. Recommendations for policy and future research

The sustainable livelihoods framework was used to analyze the differences in livelihoods and coping strategies of water-insecure smallholder rice farming households. By classifying farming households based on the determinants influencing their potential for achieving sustainable livelihoods, this typology offers valuable insights for designing intervention plans. The proposed policy recommendations are as follows.

First, since the majority of households in the clusters is vulnerable to one extreme event or the other, proactive measures can be taken to enhance the resilience and adaptive capacity of these households. This can be in the form of raising awareness, preparedness for weather-related shocks and training programs that introduce innovative agricultural practices or climate-smart technologies. Encouraging the sharing of experiences and best practices within the clusters can further enrich households' coping strategies.

Second, the age of household heads is instrumental in addressing challenges of extreme weather events. Older household heads in clusters 2, 3 and 4, may bring valuable experience and traditional knowledge, aiding in the formulation of effective strategies. However, we should also acknowledge potential limitations, such as resistance or slower adaptability to new technologies, which could impact the implementation of modern solutions. To further strengthen the resilience of households, supporting youths (cluster 1) through improved succession planning and the transfer of intergenerational knowledge can help to ensure the future strength of the farming sector.

Third, it is important to address the financial vulnerability marked by low sources of credit and utilization by households in various clusters. Implementing financial literacy programs and fostering connections with financial institutions can enhance their understanding and access to credit, thereby strengthening their financial capital. Furthermore, the absence of affiliations with community-based organizations – as shown in clusters 1 and 3 – presents an opportunity for community building. Initiatives that encourage the formation of local groups or cooperatives and incentivizing participation in these, can cultivate social capital, facilitating knowledge exchange and collaborative efforts in resilience building.

The coping and adaptive strategies of households with inadequate strategies (clusters 3 and 4) should be boosted to counter weather-related shocks. Although, cluster 4 has low vulnerability, there are still opportunities to improve their resilience. This could be executed through continuous training programs to enhance the diversity and effectiveness of their coping mechanisms, and also ensuring a dynamic response to evolving weather-related challenges.

In addition, addressing gender-specific needs and designing specific agricultural intensification interventions for larger farms could enhance the mitigation of shocks and coping strategies of rice farming households. Supportive policies through women empowerment, increased participation of women in decision-making, and community networks as well as approaches that place gender equality at the center of implementation are more effective in addressing inequalities, climate change, and fostering inclusive societies can mitigate the challenges faced by elderly and female-headed households in agriculture.

5.4. Limitations of the research

Despite the contribution to the growing literature on climate change-related adverse shocks in agriculture, this research has some limitations. First, this study has a relatively small sample size, which is primarily made up of rice farmers from a specific geographic area. It is imperative to consider that comparable contexts exist in multiple domains where the findings may hold validity or necessitate further investigation. Comparable contexts can be found in Nigeria and other sub-Saharan African nations.

Second, the conceptual framework of sustainable livelihoods was adapted from DFID (1999) whose framework consisted of five components, while the current study focused on three components only. Transforming structures and processes (the institutions, organizations, policies and legislation that shape livelihoods) were not captured because no variation in this component was found within the study area. Moreover, harvesting was still ongoing at the time of data collection and could not be captured fully into the livelihood outcomes component of the SLF.

Third, the coping strategy index developed for this study was adapted from Maxwell et al. (1999), and Maxwell and Caldwell (2008) whose framework focused on food consumption and food security-related shocks and indicators, while the indicators of coping strategies used in the current study were focused on water-related shocks. The interpretation and measurement of the frequency and severity of usage therefore differ from those that were adopted by Maxwell et al. (1999), and Maxwell and Caldwell (2008). Moreover, unlike food security risks, which are limited to specific households, natural disasters or weather-related shocks can affect entire villages, and all households in a specific village. As a result, coping strategies for climate-related events may be more limited to address household-level vulnerabilities than coping strategies for food security shocks. Nonetheless, the coping strategies of specific households remain relevant.

Finally, the researcher is responsible for cluster validity. One problem with determining the number of clusters is the subjective nature of the decision which can lead to inconsistencies and hinder the reproducibility of results. Therefore, the number of clusters should be determined carefully to avoid overlap and ensure clear characteristics. In this research, the cluster validity and the optimal number of clusters were determined by using evaluation metrics, an iterative refinement approach and expert validation.

In future research, stakeholders can build upon the findings from this research by investigating more relevant indicators of coping and adaptive strategies for climate-related events (natural disasters or water-related shocks) at household level. Panel data sets of household surveys conducted among water-insecure households may be more beneficial for identifying variations in the sustainable livelihood framework analysis that includes all of its components. Additionally, the application of other econometric analyses – such as regression analysis, factor analysis, or correlation analysis – beyond clustering analysis and cluster validity evaluation, may provide more reliable findings when evaluating the variations in the sustainable livelihoods and coping strategies of water-insecure smallholder farming households.

6. Conclusion

This research aimed to develop a typology for identifying differences in sustainable livelihoods and coping strategies for mitigating weather-related shocks by smallholder rice farming households. The study constructed a coping strategy index based on the severity and the frequency of strategy usage and then used k-means clustering analysis to group farming households according to the sustainable livelihoods framework components. The correlations between specific household characteristics and various coping strategies were also examined. The findings identify four distinct groups of water-insecure smallholder rice farming households based on the components of the SLF. By identifying the most vulnerable households, their resource endowments and coping strategies, the research provides a basis for prioritizing interventions and policies to support at-risk households during crises. This calls for a policy framework that considers context-specific approaches and local perspectives, ensuring that interventions are tailored to the unique needs and vulnerabilities of different household groups. The research outcomes can be applied in other agricultural settings where farming households face water insecurity challenges from flooding and drought, helping them to assess their livelihoods, understand their vulnerabilities and improve their coping strategies for weather-related shocks. It opens avenues for further exploration into the effectiveness of different coping mechanisms and the impact of various socio-economic factors on household resilience. Furthermore,

the construction of a coping strategy index, coupled with clustering analysis, allows for an understanding of how different household characteristics impact coping strategies. In conclusion, the research contributes valuable insights and practical tools to the literature on weather-related shocks, water insecurity, climate adaptation and resilience of rural livelihoods.

Funding

The authors disclosed receipt of NUFFIC scholarship for the research, authorship, and/or publication of this article.

CRediT authorship contribution statement

Muyinatu M. Sanusi: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Liesbeth Dries:** Writing – review & editing, Supervision, Methodology.

Declaration of competing interest

No potential conflict of interest was reported by the author(s).

Data availability

The data used in this study are not publicly available due to ethical restrictions.

Acknowledgements

The authors gratefully acknowledge financial support from NUFFIC. We gratefully acknowledge the constructive comments and suggestions from the reviewers and editors, which have significantly improved the article. We also thank the enumerators and smallholder rice farmers for their invaluable support during the data collection.

Appendix 1

Appendix 1
A List and Classification of Coping Strategies[1] based on Severity

Reversible mechanisms (temporary activity shift, disposal of protective assets) Severity weight = 1	Erosive mechanisms (disposal of productive assets) Severity weight = 2	Destitution (distress migration) Severity weight = 3
Strategies related to changing farming practices	***Mechanisms for controlling water sources***	Seek assistance from various organizations
Adding new crops/changing crop species	Rainwater harvesting techniques, storage and conservation	Stopped farming the land that was flooded
Use of drought tolerant/resistance crop varieties/seeds	Use of irrigation	Relocating to higher grounds, non-drought or unflooded area
Sustainable land management practices [e.g., cover crops, crop rotations and intercropping; compost, animal and green manure; minimum tillage, mulching and weed control; Agroforestry-trees on cropland (contours ridging, terraces, intercropping), bush and tree fallows, live barriers/buffer strips with woody species]	Constructing flood dykes, control levees, flood retention areas, groynes, drainage canals, embankment/dam, river embankments	Migration (to urban or other rural areas)
Change the timing of crop planting	Collection of run-offs from flood	Livelihood diversification (e.g. Sought off-farm employment)
General strategies related to overcoming weather-related shocks	***Mechanisms to minimise production losses***	
Relying on assistance from relatives and friends (e.g. seeking assistance in carrying out mulching, getting water from the river, borehole to a friend's farm)	Soil and erosion control	
Membership in community-based organizations (benefits from pooling resources to minimise the effects of weather-related shocks).	Pest and disease control (indirect effects of weather-related shocks)	
Using a diverse workforce (i.e. access to various categories of workers on a permanent, casual or contractual basis).	***Managerial mechanisms to minimise production losses and weather-related shocks***	
Sharing of resources and technology within the community	Can access funds for dealing with short-term disasters	
	Can access insurance coverage for major (private) assets	
	Participates in risk and vulnerability planning	
	Prepares and trains for short-term changes	
	Prepares and trains for long-term changes	

[1] These are coping strategies drawn from literature to which the indicators for constructing the Coping Strategies Index (CSI) was drawn. Similarly, prevalent strategies generated from the local context (weather-related shocks) in the study area provided the additional indicators that were considered in this study.
Source: Indicators adapted from literature (TANGO International, 2018; Maleksaeidi et al. 2016), and local context of water resources situation and water insecurity of the study area; computed from field survey data (2021)

Appendix 2

Appendix 2
Results from k-means cluster analysis with 4 clusters using standardized variables

Initial cluster centers

		Cluster			
S/N	*Variables*	*1*	*2*	*3*	*4*
1	Drought	-1.03275	1.63816	-1.92305	1.63816
2	Flood	-0.94531	2.07623	2.07623	1.32085
3	Sex	-1.34617	0.73860	-1.34617	0.73860
4	Age (years)	-1.44158	1.01316	1.15343	1.99505
5	Household size	-1.69131	0.14544	-0.64174	1.71980
6	Educational Status	0.63948	0.63948	-1.55482	0.63948
7	Rice farming experience (years)	-1.51874	0.63844	-0.84927	-1.22120
8	Soil quality	-0.02015	1.74292	-5.30936	-1.78322
9	Number of water sources	-0.47992	-0.47992	-0.47992	4.76925
10	Farm size (ha)	1.69098	-1.10557	-1.29201	1.69098
11	Trees on land (Yes/No)	0.60423	-1.64555	-1.64555	-1.64555
12	Number of productive assets owned	0.33259	-1.65163	0.99400	0.33259
13	Number of credit sources	-0.58667	1.69481	-0.58667	-0.58667
14	Credit volume (N)	-0.83977	0.88252	0.62418	-1.31340
15	Cooperative group	0.80450	0.80450	-1.23590	-1.23590
16	CSI	-0.66597	1.61643	1.90173	1.90173

Iteration History[a]

	Change in Cluster Centers			
Iteration	1	2	3	4
1	3.639	3.979	2.559	3.627
2	0.263	0.405	0.000	1.401
3	0.167	0.287	0.000	1.359
4	0.070	0.202	0.000	0.644
5	0.070	0.116	0.000	0.624
6	0.000	0.000	0.000	0.000

Final cluster centers

		Cluster			
S/N	*Variables*	*1*	*2*	*3*	*4*
1	Drought	0.02448	0.23090	-1.32952	-0.90556
2	Flood	-0.32369	0.54109	1.82444	-0.56762
3	Sex	-0.06490	0.23422	-0.65124	-0.45269
4	Age (years)	-0.50060	0.62289	0.40532	0.58733
5	Household size	-0.49688	0.64060	-0.37934	0.65148
6	Educational status	-0.02338	0.03782	-0.82339	0.16928
7	Rice farming experience (years)	-0.47812	0.75842	-0.05582	-0.06822
8	Soil Quality	-0.05688	0.20734	-4.13398	0.35765
9	Number of water sources	-0.20653	-0.16949	-0.47992	2.26964
10	Farm size (ha)	-0.04861	0.17994	-0.79484	-0.29324
11	Trees on land (Yes/No)	0.04178	0.13250	-1.64555	-0.52066
12	Number of productive assets owned	0.06390	-0.14746	0.33259	0.14362
13	Number of credit sources	-0.30148	0.22289	-0.58667	1.20592
14	Credit volume (N)	-0.24780	0.42367	0.05008	-0.18776
15	Cooperative group	-0.36448	0.47540	-0.55577	0.51302
16	CSI	-0.19344	-0.01484	0.90318	1.19867

Distances between Final Cluster Centers

Cluster	1	2	3	4
1		2.571	5.480	3.931

(*continued on next page*)

Appendix 2 (*continued*)

Distances between Final Cluster Centers				
Cluster	1	2	3	4
2	2.571		5.774	3.635
3	5.480	5.774		6.466
4	3.931	3.635	6.466	

ANOVA

		Cluster		*Error*			
S/N		Mean Square	df	Mean Square	df	*F*	*Sig.*
1	Drought	6.716	3	0.900	171	7.464	<.001
2	Flood	14.236	3	0.768	171	18.541	<.001
3	Sex	2.649	3	0.971	171	2.728	0.046
4	Age (years)	17.812	3	0.705	171	25.263	<.001
5	Household size	18.506	3	0.693	171	26.709	<.001
6	Educational status	0.859	3	1.002	171	0.857	0.465
7	Rice farming experience (years)	19.227	3	0.680	171	28.266	<.001
8	Soil Quality	18.679	3	0.690	171	27.077	<.001
9	Number of water sources	26.228	3	0.557	171	47.055	<.001
10	Farm size (ha)	1.778	3	0.986	171	1.802	0.149
11	Trees on land (Yes/No)	4.392	3	0.940	171	4.669	0.004
12	Number of productive assets owned	0.787	3	1.004	171	0.784	0.504
13	Number of credit sources	11.066	3	0.823	171	13.439	<.001
14	Credit volume (N)	5.842	3	0.915	171	6.384	<.001
15	Cooperative group	10.459	3	0.834	171	12.540	<.001
16	CSI	8.723	3	0.865	171	10.090	<.001

Number of cases in each cluster

Cluster	Frequency	Percentage (%)
1	96	54.9
2	62	35.4
3	3	1.7
4	14	8.0
Valid	175	100

The F tests should be used only for descriptive purposes because the clusters have been chosen to maximize the differences among cases in different clusters. The observed significance levels are not corrected for this and thus cannot be interpreted as tests of the hypothesis that the cluster means are equal. Large f-values provide a very good amount of separation between the various clusters and the significant level tells about variables that contributed more to the cluster formation

[a] Convergence achieved due to no or small change in cluster centers. The maximum absolute coordinate change for any center is .000. The current iteration is 6. The minimum distance between initial centers is 8.244.

Appendix 3

Appendix 3
Multiple comparisons of the clusters by the components of the Sustainable Livelihoods Framework

S/N	*Clustering Variable*	Frequency Class		*Mean Difference (I-J)*	*Sig.*	*F-Stat.*	*Sig.*
		(I) Cluster Number of Case	(J) Cluster Number of Case				
1	Drought	1	3	1.3540*	0.016	7.464	<.001
		1	4	0.9300*	<.001		
		2	3	1.5604*	0.006		
		2	4	1.1365*	<.001		
		3	1	-1.3540*	0.016		
		3	2	-1.5604*	0.006		
		4	1	-0.9300*	<.001		
		4	2	-1.1365*	<.001		
2	Flood	1	2	-0.8648*	<.001	18.541	<.001
		1	3	-2.1481*	<.001		
		2	1	0.8648*	<.001		
		2	3	-1.2833*	0.014		
		2	4	1.1087*	<.001		
		3	1	2.1481*	<.001		

(*continued on next page*)

Appendix 3 (*continued*)

S/N	Clustering Variable	Frequency Class		Mean Difference (I-J)	Sig.	F-Stat.	Sig.
		(I) Cluster Number of Case	(J) Cluster Number of Case				
		3	2	1.2833*	0.014		
		3	4	2.3921*	<.001		
		4	2	-1.1087*	<.001		
		4	3	-2.3921*	<.001		
3	Sex	2	4	0.6869*	0.02	2.728	0.046
		4	2	-0.6869*	0.02		
4	Age (years)	1	2	-1.1235*	<.001	25.263	<.001
		1	4	-1.0879*	<.001		
		2	1	1.1235*	<.001		
		4	1	1.0879*	<.001		
5	Household size	1	2	-1.1375*	<.001	26.709	<.001
		1	4	-1.1484*	<.001		
		2	1	1.1375*	<.001		
		2	3	1.0199*	0.04		
		3	2	-1.0199*	0.04		
		4	1	1.1484*	<.001		
6	Educational status	-	-	-	-	0.857	0.465
7	Rice farming experience (years)	1	2	-1.2365*	<.001	28.266	<.001
		2	1	1.2365*	<.001		
		2	4	0.8266*	<.001		
		4	2	-0.8266*	<.001		
8	Soil Quality	1	3	4.0771*	<.001	27.077	<.001
		2	3	4.3413*	<.001		
		3	1	-4.0771*	<.001		
		3	2	-4.3413*	<.001		
		3	4	-4.4916*	<.001		
		4	3	4.4916*	<.001		
9	Number of water sources	1	4	-2.4762*	<.001	47.055	<.001
		2	4	-2.4391*	<.001		
		3	4	-2.7496*	<.001		
		4	1	2.4762*	<.001		
		4	2	2.4391*	<.001		
		4	3	2.7496*	<.001		
10	Farm size (ha)	-	-	-	-	1.802	0.149
11	Trees on land (Yes/No)	1	3	1.6873*	0.003	4.669	0.004
		1	4	0.5624*	0.044		
		2	3	1.7781*	0.002		
		2	4	0.6532*	0.024		
		3	1	-1.6873*	0.003		
		3	2	-1.7781*	0.002		
		4	1	-0.5624*	0.044		
		4	2	-0.6532*	0.024		
12	Number of productive assets owned	-	-	-	-	0.784	0.504
13	Number of credit sources	1	2	-0.5244*	<.001	13.439	<.001
		1	4	-1.5074*	<.001		
		2	1	0.5244*	<.001		
		2	4	-0.9830*	<.001		
		3	4	-1.7926*	0.002		
		4	1	1.5074*	<.001		
		4	2	0.9830*	<.001		
		4	3	1.7926*	0.002		
14	Credit volume (N)	1	2	-0.6715*	<.001	6.384	<.001
		2	1	0.6715*	<.001		
		2	4	0.6114*	0.032		
		4	2	-0.6114*	0.032		
15	Cooperative group	1	2	-0.8399*	<.001	12.54	<.001
		1	4	-0.8775*	<.001		
		2	1	0.8399*	<.001		
		4	1	0.8775*	<.001		
16	CSI	1	3	-1.0966*	0.046	10.09	<.001
		1	4	-1.3921*	<.001		
		2	4	-1.2135*	<.001		
		3	1	1.0966*	0.046		
		4	1	1.3921*	<.001		
		4	2	1.2135*	<.001		

* The mean difference is significant at the 0.05 level.

References

Adjognon, S.G., Liverpool-Tasie, L.S.O., Reardon, T.A., 2017. Agricultural input credit in Sub-Saharan Africa: telling myth from facts. Food Pol. 67, 93–105. https://doi.org/10.1016/j.foodpol.2016.09.014.

Aijazi, O., Basu, S., Relativo, E., Tc, E., Chair, A.A., Ruiz, M., Adhikari, A., Adhikari, A., Adjima, J., Chaudhary, R., Chettri, N., Dorji, T., Gerritsen, P., Ghosh, S., Gurung, J., Gurung, K., Koumi, V., Leone, P., Mathur, V., Yumnam, R., 2021. Critical Approaches to Gender in Mountain Ecosystems. International Union for Conservation of Nature. https://doi.org/10.2305/iucn.ch.2021.17.en.

Ajah, E.A., Ofem, U.I., Effa, E.B., Ubabuko, L.I., 2022. Analysis of risk management practices among cassava farmers in ideato south local government area, imo state, Nigeria. Afr. J. Food Nutr. Sci. 22 (3), 19871–19885.

Akanbi, S.-U.O., Olatunji, O.S., Oladipo, O.S., Adeyemi, U.T., Akinyoade, A., 2022. Vulnerability of rice farmers to climate change in kwara state, Nigeria. Turkish Journal of Agriculture - Food Science and Technology 10 (2), 374–380. https://doi.org/10.24925/turjaf.v10i2.374-380.4648.

Akinwumi, A., 2013. Rice consumption and importation in Nigeria, no solution in sight. http://www.vanguardngr.com/2013/12/rice-consumption-importation-nigeria-solution-sight/. (Accessed 19 November 2023).

Akpan, S.B., Udoh, E.J., Patrick, I.V., 2016. Sustaining small scale farming: evidence of poverty and income disparity among rural farming households in south-south region of Nigeria. Path of Science: International Electronic Scientific Journal 2, 9–22. https://doi.org/10.22178/pos.14-5.

Akter, S., Basher, S.A., 2014. The impacts of food price and income shocks on household food security and economic well-being: evidence from rural Bangladesh. Global Environ. Change 25, 150–162. https://doi.org/10.1016/j.gloenvcha.2014.02.003.

Alinovi, L., D'errico, M., Mane, E., Romano, D., 2010. Livelihoods strategies and household resilience to food insecurity: an empirical analysis to Kenya. European report on development 1 (1), 1–52.

Ansah, I.G.K., 2021. Household Resilience to Food Security Shocks [PhD thesis. Wageningen University, Wageningen, the Netherlands. June, pp. 1–171. ISBN: 978-94-6395-688-8.

Ansah, I.G.K., Gardebroek, C., Ihle, R., 2021. Shock interactions, coping strategy choices and household food security. Clim. Dev. 13 (5), 414–426. https://doi.org/10.1080/17565529.2020.1785832.

Arouri, M., Nguyen, C., Youssef, A.B., 2015. Natural disasters, household welfare, and resilience: evidence from rural vietnam. World Dev. 70, 59–77. https://doi.org/10.1016/j.worlddev.2014.12.017.

Asfaw, A., Admassie, A., 2004. The role of education on the adoption of chemical fertilizer under different socioeconomic environments in Ethiopia. Agric. Econ. 30 (3), 215–228.

Ashraf, M., Routray, J.K., 2013. Perception and understanding of drought and coping strategies of farming households in north-west Balochistan. Int. J. Disaster Risk Reduc. 5, 49–60. https://doi.org/10.1016/j.ijdrr.2013.05.002.

Awolala, D.O., Ajibefun, I.A., 2015. Rice farmers' vulnerability to extreme climate: deploying local adaptation finance in ekiti state, Nigeria. World Environ. 5 (3), 91–100.

Ayana, G.F., Megento, T.L., Kussa, F.G., 2021. The extent of livelihood diversification on the determinants of livelihood diversification in Assosa Wereda, Western Ethiopia. Geojournal 87 (4), 2525–2549. https://doi.org/10.1007/s10708-021-10379-5.

Baker, H.S., Millar, R.J., Karoly, D.J., Beyerle, U., Guillod, B.P., Mitchell, D., Shiogama, H., Sparrow, S., Woollings, T., Allen, M.R., 2018. Higher CO_2 concentrations increase extreme event risk in a 1.5 °c world. Nat. Clim. Change 8 (7), 604–608. https://doi.org/10.1038/s41558-018-0190-1.

Bekele, A.E., 2022. The Impacts of Large-Scale Land Investments on Agropastoral Livelihoods in Ethiopia [PhD thesis. Wageningen University, Wageningen, the Netherlands].

Bello, L.O., Baiyegunhi, L.J.S., Danso-Abbeam, G., 2021. The productivity impact of improved rice varieties' adoption: the case of smallholder rice farmers in Nigeria. Econ. Innovat. N. Technol. 30 (7), 750–766. https://doi.org/10.1080/10438599.2020.1776488.

Berchoux, T., Watmough, G.R., Hutton, C.W., Atkinson, P.M., 2019. Agricultural shocks and drivers of livelihood precariousness across Indian rural communities. Landsc. Urban Plann. 189, 307–319. https://doi.org/10.1016/j.landurbplan.2019.04.014.

Bezlepkina, I.V., 2004. Microeconomic Analysis of Russian Agricultural Enterprises with Special Reference to Subsidies and Debts [PhD thesis. Wageningen University, Wageningen, the Netherlands]. https://edepot.wur.nl/121603.

Birthal, P.S., Roy, D., Negi, D.S., 2015. Assessing the impact of crop diversification on farm poverty in India. World Dev. 72, 70–92. https://doi.org/10.1016/j.worlddev.2015.02.015.

Boansi, D., Owusu, V., Tambo, J.A., Donkor, E., Asante, B.O., 2021. Rainfall shocks and household welfare: evidence from northern Ghana. Agric. Syst. 194, 103267 https://doi.org/10.1016/j.agsy.2021.103267.

Brown, P.R., Tuan, V.V., Nhan, D.K., Dung, L.C., Ward, J., 2018. Influence of livelihoods on climate change adaptation for smallholder farmers in the Mekong Delta Vietnam. Int. J. Agric. Sustain. 16 (3), 255–271. https://doi.org/10.1080/14735903.2018.1472858.

Carleton, T.A., Hsiang, S.M., 2016. Social and economic impacts of climate. Science 353 (6304).

Castaneda, R.A., Doan, D.D.T., Newhouse, D.L., Nguyen, M.C., Uematsu, H., Azevedo, J.P.W.D., 2018. A new profile of the global poor. World Dev. 101, 250–267 also available at: https://www.sciencedirect.com/science/article/pii/S0305750X17302735.

Chambers, R., 1989. Editorial introduction: vulnerability, coping and policy. IDS Bull. 20 (2), 1–7.

Chambers, R., Conway, G., 1992. Sustainable Rural Livelihoods: Practical Concepts for the 21st Century. IDS Discussion Paper 296. Brighton. Institute of Development Studies.

Chambers, R., 2009. Climate Vulnerability and Capacity Analysis. Institute of Development Studies University of Sussex, UK.

Chamdimba, O.Y., Ortmann, G.F., Wale, E., 2020. Resilience to shocks and food insecurity: determinants, and the impact of smallholder jatropha curcas cultivation in Southern Malawi. African Journal of Science, Technology, Innovation and Development 13 (5), 619–633. https://doi.org/10.1080/20421338.2020.1774962.

Chavas, J.P., 2019. Adverse shocks in agriculture: the assessment and management of downside risk. J. Agric. Econ. 70 (3), 731–748. https://doi.org/10.1111/1477-9552.12312.

Chen, H., Zhu, T., Krott, M., Calvo, J.F., Ganesh, S.P., Makoto, I., 2013. Measurement and evaluation of livelihood assets in sustainable forest commons governance. Land Use Pol. 30 (1), 908–914. https://doi.org/10.1016/j.landusepol.2012.06.009.

Cole, S., Giné, X., Tobacman, J., Topalova, P., Townsend, R., Vickery, J., 2013. Barriers to household risk management: evidence from India. Am. Econ. J. Appl. Econ. 5 (1), 104–135.

Corbett, J., 1988. Famine and household coping strategies. World Dev. 16 (9), 1099–1112. https://doi.org/10.1016/0305-750X(88)90112-X.

Cormack, R.M., 1971. A review of classification. J. Roy. Stat. Soc. 134, 321–367.

Davies, S., 1996. Adaptable Livelihoods: Coping with Food Insecurity in the Malian Sahel. Macmillan Press, London.

Demetriades, J., Esplen, E., 2008. The gender dimensions of poverty and climate change adaptation. IDS Bull. 39, 24–31. https://doi.org/10.1111/j.1759-5436.2008.tb00473.x.

Dercon, S., Hoddinott, J., Woldehanna, T., 2005. Shocks and consumption in 15 Ethiopian villages, 1999-2004. J. Afr. Econ. 14 (4), 559–585. https://doi.org/10.1093/jae/eji022. (Accessed 13 August 2005).

Deressa, T.T., Hassan, R.M., Ringler, C., Alemu, T., Yesuf, M., 2009. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. Global Environ. Change 19 (2), 248–255. https://doi.org/10.1016/j.gloenvcha.2009.01.002.

DFID, 2000. Sustainable Rural Livelihoods Guidance Sheet, London, UK.

DFID, 1999. Sustainable livelihoods guidance sheets. London: DFID 445.

Doss, C.R., Morris, M.L., 2000. How does gender affect the adoption of agricultural innovations? Agric. Econ. 25, 27–39.

Duru, J., Aro, J., Oladipo, R.E., 2022. The effects of climate change on the livelihood of rural women: a case study of ilorin south, Nigeria. Bull. Natl. Res. Cent. 46, 165. https://doi.org/10.1186/s42269-022-00834-9.

Elasha, B.O., Elhassan, N.G., Ahmed, H., Zakieldin, S., 2005. Sustainable livelihood approach for assessing community resilience to climate change: case studies from Sudan. Assessment of impacts and adaptations to climate change (AIACC) Working Paper No 17, 1-26. Available form www.aiaccproject.org.
Ellis, F., 1998. Household strategies and rural livelihood diversification. J. Dev. Stud. 35 (1), 1–38. https://doi.org/10.1080/00220389808422553.
Everitt, B.S., Landau, S., Leese, M., Stahl, D., 2011. Cluster Analysis, fifth ed. John Wiley & Sons, Chichester, UK.
Everitt, B., Hothorn, T., 2011. An Introduction to Applied Multivariate Analysis with R. Springer, New York. https://doi.org/10.1007/978-1-4419-9650-3.
FAO, 2016. Smallholder productivity under climatic variability: adoption and impact of widely promoted agricultural practices in Tanzania. In: Arslan, Aslihan (Ed.), Federico Belotti and Leslie Lipper. FAO, Rome. ESA Working Paper No. 16-03.
FAO, 2011. The state of food and agriculture. Women in Agriculture, Closing the Gender Gap for Development. Food and Agriculture Organization of the United Nations, Rome.
FAO, IFAD, Unicef, WFP, WHO, 2018. The State of Food Security and Nutrition in the World: Building Climate Resilience for Food Security and Nutrition. FAO. Licence: CC BY-NC-SA 3.0 IGO, Rome.
Farrington, J., Ramasut, T., Walker, J., 2002. Sustainable livelihoods approaches in urban areas: general lessons, with illustrations from Indian cases. Working Paper 162, Results of ODI Research Presented in Preliminary Form for Discussion and Critical Comment. ISBN: 0 85003 576 7.
Fisher, R.A., 1935. Design of Experiments. Oliver & Boyd, London.
Fjelde, H., von Uexkull, N., 2012. Climate triggers: rainfall anomalies, vulnerability and communal conflict in sub-Saharan Africa. Polit. Geogr. 31 (7), 444–453.
Frankenberger, T., Langworthy, M., Spangler, T., Nelson, S., 2012. Enhancing resilience to food security shocks. White Paper (DRAFT). TANGO International Inc., pp. 1–59
Gordon, A.D., 1999. Classification, second ed. Chapman and Hall/CRC, Boca Raton, FL.
Gwimbi, P., 2009. 'Linking rural community livelihoods to resilience building in flood risk reduction in Zimbabwe', JÀMBÁ. Journal of Disaster Risk Studies 2 (1), 71–79. https://doi.org/10.4102/jamba.v2i1.16.
Hair, J.F., Black, W.C., Babin, B.J., Anderson, R.E., 2019. Multivariate Data Analysis, eighth ed. Publisher: Annabel Ainscow. ISBN: 978-1-4737-5654-0.
Hair, J.F., Black, W.C., Babin, B.J., Anderson, R.E., 2010. Multivariate Data Analysis, seventh ed. Publisher: Pearson Prentice Hall.
Hair, J.F., Anderson, R.E., Tatham, R.L., Black, W.C., 1992. Multivariate Data Analysis, third ed. Macmillan, New York.
Hallegatte, S., Rozenberg, J., 2017. Climate change through a poverty lens. Nat. Clim. Change 7 (4), 250–256. https://doi.org/10.1038/nclimate3253.
Hallegatte, S., Bangalore, M., Bonzanigo, L., Fay, M., Kane, T., Narloch, U., Rozenberg, J., Treguer, D., Vogt-Schilb, A., 2016. Shock Waves-Managing the Impacts of Climate Change on Poverty. World Bank, Washington, DC.
Han, J., Kamber, M., Pei, J., 2012. Data Mining: Concepts and Techniques, third ed. Morgan Kaufmann Publishers.
Han, J., Kamber, M., 2006. Data Mining: Concepts and Techniques, second ed. Morgan Kaufmann Publishers.
Haq, S.M.A., Ahmed, K.J., Islam, M.N., Hussain, A.H.M.B., Islam, M., 2021. Climate change, debate and dimensions of coping strategies. In: Leal Filho, W., Luetz, J., Ayal, D. (Eds.), Handbook of Climate Change Management. Springer, Cham. https://doi.org/10.1007/978-3-030-22759-3_16-1.
Headey, D., 2011. Rethinking the global food crisis: the role of trade shocks. Food Pol. 36, 136–146.
Hendrix, C.S., Salehyan, I., 2012. Climate change, rainfall, and social conflict in Africa. J. Peace Res. 49 (1), 35–50. https://doi.org/10.1177/0022343311426165.
Ibrahim, M.G.P., Alex, R.S., 2009. The impact of changing environmental conditions on vulnerable communities in the Shire Valley, Southern Malawi. In: Lee, C., Schaaf, T. (Eds.), The Future of Drylands SE-49. Springer, Netherlands, pp. 545–559.
Igwenagu, E., 2021. Ogun State population. https://nigerianinformer.com/ogun-state-population/ (Accessed 09 August 2023).
Jaka, H., Shava, E., 2018. Resilient rural women's livelihoods for poverty alleviation and economic empowerment in semi-arid regions of Zimbabwe. JÀMBÁ: Journal of Disaster Risk Studies, (Potchefstroom, South Africa) 10 (1), 524. https://doi.org/10.4102/jamba.v10i1.524.
Just, R.E., Pope, R.D., 2002. A Comprehensive Assessment of the Role of Risk in U.S. Agriculture. Kluwer Academic Publishers, Boston, MA.
Kabeer, N., 2005. Gender equality and women's empowerment: a critical analysis of the third millennium development goal. Gend. Dev. 13 (1), 13–24. https://www.jstor.org/stable/20053132.
Kalkuhl, M., von Braun, J., Torero, M., 2016. Food Price Volatility and its Implications for Food Security and Policy. Springer International Publishing AG, Cham, Switzerland.
Kanji, N., MacGregor, J., Tacoli, C., 2005. Understanding Market-Based Livelihoods in a Globalizing World: Combining Approaches and Methods. International Institute for Environment and Development (IIED).
Kassie, M., Teklewold, H., Jaleta, M., Marenya, P., Erenstein, O., 2015. Understanding the adoption of a portfolio of sustainable intensification practices in eastern and southern Africa. Land Use Pol. 42, 400–411. https://doi.org/10.1016/j.landusepol.2014.08.016.
Kassie, M., Jaleta, M., Shiferaw, B., Mmbando, F., Mekuria, M., 2013. Adoption of interrelated sustainable agricultural practices in smallholder systems: evidence from rural Tanzania. Technol. Forecast. Soc. Change 80, 525–540.
Keshavarz, M., Moqadas, R.S., 2021. Assessing rural households' resilience and adaptation strategies to climate variability and change. J. Arid Environ. 184 (1–8) https://doi.org/10.1016/j.jaridenv.2020.104323. ISSN 0140-1963.
Ketchen, D.J., Shook, C.L., 1996. The application of cluster analysis in strategic management research: an analysis and critique. Strat. Manag. J. 17 (6), 441–458. https://www.jstor.org/stable/2486927.
Ketchen, D.J., Thomas, J.B., Snow, C.C., 1993. Organizational configurations and performance: a comparison of theoretical approaches. Acad. Manag. J. 36 (6), 1278–1313. https://doi.org/10.2307/256812.
Kettenring, J.R., 2006. The practice of cluster analysis. J. Classif. 23 (1), 3–30. https://doi.org/10.1007/s00357-006-0002-6.
Kollmair, M., Gamper, S., 2002. The Sustainable Livelihood Approach. Input Paper for the Integrated Training Course of NCCR North-South. Development Study Group. University of Zurich.
Komarek, A.M., De Pinto, A., Smith, V.H., 2020. A review of types of risks in agriculture: what we know and what we need to know. Agric. Syst. 178, 102738.
Krantz, L., 2001. The sustainable livelihood approach to poverty reduction. SIDA. Division for Policy and Socio-Economic Analysis 44.
Krishnan, P., Dercon, S., 2000. Vulnerability, seasonality and poverty in Ethiopia. J. Dev. Stud. 36 (6), 25–51.
Leight, J., 2020. The impact of positive agricultural income shocks on rural Chinese households. World Bank Econ. Rev. 34 (1), 210–231. https://doi.org/10.1093/wber/lhy008.
Linh, T.N., Long, H.T., Chi, L.V., Tam, L.T., Lebailly, P., 2019. Access to rural credit markets in developing countries, the case of Vietnam: a literature review. Sustainability 11, 1468. https://doi.org/10.3390/su11051468.
Longhurst, R., 1986. Household food strategies in response to seasonality and famine. IDS Bull. 17 (3), 27–35.
Maddison, D., 2007. The perception of and adaptation to climate change in Africa. (Vol. 4308). World Bank Publications.
Maleksaeidi, H., Karami, E., Zamani, G.H., Rezaei-Moghaddam, K., Hayati, D., Masoudi, M., 2016. Discovering and characterizing farm households' resilience under water scarcity. Environ. Dev. Sustain. 18, 499–525. https://doi.org/10.1007/s10668-015-9661-y.
Matsa, M., Simphiwe, M., 2014. Grappling climate change in southern Zimbabwe: the experience of bakalanga minority farmers. Sacha J. Environ. Stud. 4 (1), 34–52.
Maxwell, D., Caldwell, R., 2008. The Coping Strategies Index: Field Methods Manual, second ed. Cooperative for Assistance and Relief Everywhere, Inc.(CARE). In: http://documents.wfp.org/stellent/groups/public/documents/manual_guide_proced/wfp211058.pdf. (Accessed 9 March 2022).
Maxwell, D., Watkins, B., Wheeler, R., Collins, G., 2003. The coping strategies index: a tool for rapidly measuring food security and the impact of food aid programs in emergencies. Nairobi: CARE Eastern and Central Africa Regional Management Unit and the World Food Programme Vulnerability Assessment and Mapping Unit. (Accessed 19 November 2023).
Maxwell, D., 1996. Measuring food insecurity: the frequency and severity of 'coping strategies'. Food Pol. 21 (3), 291–303.
Maxwell, D., Ahiadeke, C., Levin, C., Armar-Klemesu, M., Zakariah, S., Lamptey, G.M., 1999. Alternative food-security indicators: revisiting the frequency and severity of 'coping strategies'. Food Pol. 24, 411–429.
Mazzocchi, M., Montresor, E., 2000. A multivariate statistical approach to the analysis of rural development. Agric. Econ. Rev. 1 (2), 31–45. http://ageconsearch.umn.edu/record/26455/files/01020027.pdf.

Mendelsohn, R., 2007. What causes crop failure? Climatic Change 81, 61–70.
Milligan, G.W., Cooper, M.C., 1988. A study of standardization of variables in cluster analysis. J. Classif. 5, 181–204. https://doi.org/10.1007/BF01897163.
Montgomery, R., 1996. Disciplining or protecting the poor? Avoiding the social costs of peer pressure in micro-credit schemes. J. Int. Dev. 8 (2), 289–305.
Nangoma, E., 2007. National adaptation strategy to climate change impacts: a case study of Malawi: human development occasional papers (1992–2007). Human Development Report Office (HDRO), UNDP, 1-46. https://hdr.undp.org/system/files/documents/nangomaeverhartmalawi.pdf. (Accessed 8 September, 2022).
Nasrnia, F., Ashktorab, N., 2021. Sustainable livelihood framework-based assessment of drought resilience patterns of rural households of Bakhtegan basin, Iran. Ecol. Indicat. 128, 107817.
Natarajan, N., Newsham, A., Rigg, J., Suhardiman, D., 2022. A sustainable livelihoods framework for the 21st century. World Dev. 155, 1–15. https://doi.org/10.1016/j.worlddev.2022.105898.
NBS, 2019a. Annual Abstract of Statistics. National Bureau of Statistics, Abuja, Nigeria.
NBS, 2019b. National Population Estimates. National Bureau of Statistics, Abuja, Nigeria. https://www.google.com/url?sa=t&source=web&rct=j&url=https://nigerianstat.gov.ng/download/474&ved=2ahUKEwig1r39hPX3AhU0RuUKHTlTBg8QFnoECCwQAQ&usg=AOvVaw0BYliCMVsVxpAo4Ie9xgup.
Nelson, G.C., Valin, H., Sands, R.D., Havlık, P., Ahammad, H., Deryng, D., Elliott, J., Fuji-mori, S., Hasegawa, T., Heyhoe, E., Kyle, P., Von Lampe, M., Lotze-Campen, H., Mason d'Croz, D., van Meijl, H., van der Mensbrugghe, D., M€uller, C., Popp, A., Robertson, R., Robinson, S., Schmid, E., Schmitz, C., Tabeau, A., Willenbockel, D., 2014. Climate change effects on agriculture: economic responses to biophysical shocks. Proc. Natl. Acad. Sci. U.S.A. 111 (9), 3274–3279. https://doi.org/10.1073/pnas.1222465110.
Newman, C., Tarp, F., 2020. Shocks and agricultural investment decisions. Food Pol. 94, 1–9. https://doi.org/10.1016/j.foodpol.2019.101810.
Nhemachena, C., Hassan, R., 2007. Micro-level analysis of farmers' adaptation to climate change in Southern Africa. IFPRI Discussion Paper No. 00714, Washington, DC. https://ageconsearch.umn.edu/record/42399.
Nigeria Galleria, 2021. A brief history of Ogun State. https://www.nigeriagalleria.com/Nigeria/States_Nigeria/Ogun/Brief-History-of-Ogun-State.html.
Nyberg, Y., Wetterlind, J., Jonsson, M., Öborn, I., 2021. Factors affecting smallholder adoption of adaptation and coping measures to deal with rainfall variability. Int. J. Agric. Sustain. 19 (2), 175–198. https://doi.org/10.1080/14735903.2021.1895574.
OGADEP, 2005. Ogun State Agricultural Development Programme Annual Report, Planning, Research and Statistics. Ministry of Agriculture, Abeokuta, Nigeria.
Papaioannou, K.I., de Haas, M.A., 2015. Climate shocks, cash crops and resilience: evidence from colonial tropical africa. CGEH Working Paper Series; No. 76). Centre for Global Economic History. http://www.cgeh.nl/sites/default/files/WorkingPapers/cgehwp76_papaioannoudehaas.pdf.
Pasteur, K., 2011. From Vulnerability to Resilience: A Framework for Analysis and Action to Build Community Resilience. Practical Action, Rugby.
Sawada, Y., 2006. The Impact of Natural and Manmade Disasters on Household Welfare. Graduate School of International Development, Nagoya University, Japan. Discussion Paper 148.
Scoones, I., 2015. Sustainable Rural Livelihoods and Rural Development. Practical Action Publishing and Winnipeg, CA: Fernwood Publishing, UK.
Scoones, I., 1998. Sustainable Rural Livelihoods, a Framework for Analysis. IDS working paper number 72, Brighton.
Sen, A., 1999. Development as Freedom, first ed. Oxford University Press, New York. ISBN 9780198297581.
Serrat, O., 2017. The sustainable livelihoods approach. In: Knowledge Solutions. Springer, pp. 21–26. https://doi.org/10.1007/978-981-10-0983-9_5.
Singh, N., Gilman, J., 1999. 'Making livelihoods more sustainable. Int. Soc. Sci. J. 51 (4), 539–545.
Silvestri, S., Bryan, E., Ringler, C., Herrero, M., Okoba, B., 2012. Climate change perception and adaption of agro-pastoral communities in Kenya. Reg. Environ. Change 12 (4), 791–802.
TANGO International, 2018. Methodological guide: a guide for calculating resilience capacity. Resilience Evaluation, Analysis and Learning (REAL) Associate Award. https://www.fsnnetwork.org/sites/default/files/Methodology_Guide_Nov2018508.pdf. (Accessed 02 November, 2021).
Teklewold, H., Kassie, M., Shiferaw, B., 2013. Adoption of multiple sustainable agricultural practices in rural Ethiopia. J. Agric. Econ. 64, 597–623.
Tesliuc, E.D., Lindert, K., 2002. Vulnerability: a quantitative and qualitative assessment. Guatemala poverty assessment program. World Bank Social Protection Discussion Paper No. 0404, 1-91. Washington, DC.
Thulstrup, A.W., 2015. Livelihood resilience and adaptive capacity: tracing changes in household access to capital in central vietnam. World Dev. 74, 352–362. https://doi.org/10.1016/j.worlddev.2015.05.019.
Udoh, E.J., Akpan, S.B., Uko, E.F., 2017. Assessment of sustainable livelihood assets of farming households in Akwa Ibom State, Nigeria. J. Sustain. Dev. 10 (4), 83–96. https://doi.org/10.5539/jsd.v10n4p83.
Vivek, K.S., 2019. Assessment of Livelihoods of Smallholder Rice Farmers in Aurangabad District, Bihar, India. Van Hall Larenstein University of Applied Sciences, the Netherlands [MSc thesis.
WCED, 1987. Food 2000: Global Policies for Sustainable Agriculture, a Report of the Advisory Panel on Food Security, Agriculture, Forestry and Environment to the World Commission on Environment and Development. Zed Books Ltd, London and New Jersey.
Wisner, B., Blaikie, P., Cannon, T., Davis, I., 2004. At Risk: Natural Hazards, People's Vulnerability and Disasters. Routledge, Oxford, UK.
WFP, 2009. Comprehensive Food Security and Vulnerability Analysis (CFSVA) Guidelines. WFP Food Security Analysis Service. January.
WPR, 2022. Nigeria population 2022 (live). https://worldpopulationreview.com/countries/Nigeria-population.WorldPopulationReview. Walnut, United States.
Yadav, S.K., Banerjee, A., Jhariya, M.K., Meena, R.S., Raj, A., Khan, N., Kumar, S., Sheoran, S., 2022. Enviromental education for sustainable development. In: Natural Resources Conservation and Advances for Sustainability, pp. 415–431. https://doi.org/10.1016/B978-0-12-822976-7.00010-7.
Yegbemey, R.N., Yegbemey, E.O., Yabi, J.A., 2017. Sustainability analysis of observed climate change adaptation strategies in maize farming in Benin, West Africa. Outlook Agric. 46 (1), 20–27. https://doi.org/10.1177/0030727016689638.