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Vulnerability to resilience for smallholder, small grain farmers in Southern Zimbabwe: The case of semi-arid regions of Southern Zimbabwe

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ABSTRACT

Small grain production provides hope for farmers in regions affected by climate change. This study determined the levels of smallholder, small grain farmers' vulnerability and resilience using data collected from four districts (Binga, Chiredzi, Hwange and Matobo) in Zimbabwe's agro-ecological regions 1V and V. A mixed method approach was used to collect data from 281 respondents. A multistage sampling approach with a purposive selection of districts dominant in small grain production was conducted. For each district, two wards were selected randomly. Stata version (16) was used to analyse the data. Factor analysis and Agricultural Drought Index (ADRI) were used to quantify farmer vulnerability and resilience. Results show that 46.3% were in the medium vulnerability group while 26% were highly vulnerable. Districts on contract farming were less vulnerable than districts on non-contract farming. Farmer resilience varied with location, with Chiredzi having the highest (ADRI 4.56) and Matobo the least (ADRI 3.32). The study made three recommendations; the production of improved small grain varieties in regions IV and V, the practice of conservation agriculture as an adaptation strategy to climate change and aggressive enforcement of agricultural policies relating to the production of small grain on contract farming.

Keywords: *Climate change; small grain; adaptation strategy; vulnerability; resilience; smallholder*

1 Introduction

Globally, agriculture remains the mainstay of economic activity and a key issue for sustainable livelihoods. In Zimbabwe, the majority of the population lives in rural areas where livelihoods are hinged on agriculture. Climate change poses a significant threat to smallholder farmers and it threatens to undermine community progress towards poverty alleviation, food security and sustainable development. Smallholder farmers are highly vulnerable to climate change because most depend on rain-fed agriculture, cultivate marginal areas and lack access to information and financial support that could help them invest in more climate-resilient agriculture. While smallholder farmers in these semi-arid regions grow both small grains and maize crops, the adoption of improved small grain seed remains low despite the perennial meagre returns that are realised from the preferred maize crops. Regardless of evidence supporting our argument, high levels of vulnerability to smallholder, small grain farmers in some regions are of great concern. The need to graduate smallholder small grain farmers from vulnerability to resilience through climate variability coping mechanisms against shocks and stresses cannot be overemphasised. The objectives of the study were to: 1. identify the climatic adaptation strategies used by smallholder, small grain farmers in the drought prone areas of Zimbabwe. 2. determine the levels of smallholder, small grain farmers' vulnerability and resilience to food insecurity in the drought prone areas of Zimbabwe.3. recommend policies for reducing smallholder small grain farmers' vulnerability by enhancing resilience to climate change risks. A mixed method approach was used to collect data from 281 respondents. Factor analysis and Agricultural drought index (ADRI) were used to quantify farmer vulnerability and resilience. Understanding the impacts of climate change on smallholder farmers and developing appropriate adaptation strategies are critical, where small-scale agriculture is central to economic development, food security and resilience. In this paper, we argue that small grain production takes away the guess work by providing a better strategy to hedge against climate change shocks and stresses in semi-arid regions. By gaining more resilience or reducing vulnerability, this will increase smallholder farmers' capacity to adapt to climate change impacts and thus improve livelihood strategies by increasing food and nutrition security.

1.1 Background and conceptual basis

All nations of the world have committed themselves to surmounting the twin challenges of poverty and hunger through comprehensive and sustainable ways (United Nations, 2015). A report by the United Nations warned that the world was faced with multiple and complex climatic change-induced challenges in the 21st century and beyond (FAO, 2016). Food insecurity in the face of a growing population was one of the world's colossal challenges that required evidence-based solutions. Food security is a priority issue among the 17 Sustainable Development Goals (SDGs) that are integrated but adaptable to the specific needs of each nation.

Various studies concur that food security is a global issue that can be addressed by the adoption of drought- tolerant crops (FAO, 2016; Muchuru and Nhamo, 2019; Glover et al., 2020). Substantial evidence suggests that the growing of small grains is the panacea to perennial food insecurity in arid regions that are victims of climatic change (Mathew, 2015; Muchuru and Nhamo, 2019; Glover et al., 2020). The argument is that small grains are adaptable to harsh weather conditions and improve agricultural productivity leading to resilient communities. Research shows that this can be achieved without the need for rural populations resorting to irreversible ecological degradation in their bid to sustain their livelihoods (Mathew, 2015). Evidence shows that production of sorghum and finger millet was low during the 1990s. However, with the growing impacts of climate change on maize, drought-resistance crops have been gaining the interest of farmers. This evidence reveals that small grains can be successfully used as an adaptation strategy to alleviate food shortages, strengthen grain reserves and build resilience (Ndlovu et al., 2020). Annual rainfall levels, based on the 1961–90 average, are also projected to decline between 5–20 per cent by 2080 in all of the country's major river basins and these projections will worsen the existing deficiency of water resources, particularly in Zimbabwe's agro-ecological zones IV and V (FAO, 2016). Thus, the trends show how Zimbabwe is increasingly becoming food-insecure, pointing to the need for the adoption of small grains by communities that are vulnerable to the impacts of climate change (Nyahunda and Tirivangasi, 2019). Emphasising the rationale for increasing food production amid climate change challenges, Andaluz (2018) opined that the world was operating in a circular economy where economic, environmental and social impacts must be considered simultaneously. There have been more and more voices from different parts of the globe advocating for the adoption of crops and cultivars which can adapt to semi-arid conditions (Muzari et al., 2013; Mathew, 2015; Muchuru and Nhamo, 2019).

Despite the calls that are supported by empirical evidence, some smallholder farmers in arid ecological regions are hesitant to adopt small grains as a resilience-building strategy to hedge against climate change. In Zimbabwe, natural regions IV and V are semi-arid areas that experience low annual rainfall of 450-650 mm. Periodic seasonal droughts and prolonged dry spells are common features in these two regions. These regions are not suitable for the production of maize grain, which is the most preferred staple food in Zimbabwe. While smallholder farmers in these semi-arid regions grow both small grains and maize crops, the adoption of improved small grain seed remains low despite the perennial meagre returns that are realised from the preferred crops (Mukarumbwa and Mushunje, 2010; Muchuru and Nhamo, 2019). This study was conducted to determine how small grain farmers could use small grain improved seed varieties and conservation agriculture as an adaptive strategy to climate change impacts thereby graduating farmers from a vulnerable to a resilience state.

This study employed a conceptual framework for resilience analysis, drawing on attributes from the livelihood approach, disaster risk reduction, and climate change adaptation (Frankenberger et al., 2012). The framework was chosen because it emphasises productive assets and livelihood strategies that help smallholder farmers' transition from vulnerability to resilience. The framework encompasses various components, including context, level of aggregation, disturbance, exposure, adaptive capacity, sensitivity, resilience and vulnerability pathways, and livelihood outcomes, such as food security. Consequently, the framework is highly relevant to the study as it connects resilience pathways to food security within a specific context, encompassing both pre-shock preparedness and prevention, as well as post-shock response and recovery mechanisms. Strong ex-ante preparedness reduces the likelihood of households experiencing food insecurity during shocks. Moreover, resilience-building is viewed as a transformative process that permanently lifts individuals out of vulnerability, achieved through strengthening livelihoods, disaster preparedness, enhancing adaptive capacity, and addressing governance factors. The framework aligns well with our study's focus on assessing vulnerability and resilience among smallholder, small grain farmers.

The study adopted the Sustainable Livelihoods Framework (SLF) developed by the Department for International Development (DFID, 1999). This framework was utilised to assess the levels of resilience among smallholder, small grain farmers and enhance their capacities and adaptation capabilities at the individual household and institutional levels (Ndlovu et al., 2020). By employing the SLF as a set of principles and an analytical framework, the study aimed to identify the various forms of capital (human, social, natural, physical, and financial) present or lacking within smallholder farming systems, which influence their climate-adaptive strategies and capacities (DFID, 1999; Wright et al., 2012). In selecting this theoretical framework, we considered that although a smallholder farmer's choice of livelihood strategy influences his or her level of food security and income, it is also possible that the farmer's level of food security can also affect which livelihood strategy he or she adopts (Farrington and John, 2001). According to Ndlovu et al. (2020) and Wright et al. (2012), livelihood assets determine the farmer's level and path of development in the wake of climate change and variability. The SLF, therefore, proved to be the most appropriate lens to underpin this study.

2 Literature Review

Resilience emphasises the capacity to avoid, or adapt to, unexpected changes to sustain one's well-being, whether or not such dependence is recognised (Clark, 2007; Biggs et al., 2015). While resilience is a set of responses that may counter the structural and stochastic factors that allow households to be vulnerable when exposed to some set of shocks and stressors, vulnerability is the absence of resilience during a catastrophe (Aguilar et al., 2021). Resilience and vulnerability are, thus, indispensable sides of the same coin. The development of resilience measures in this study takes into account the aftermath of a shock as the result of a number of ex-post mitigation measures.

Shifting climatic conditions in Africa have dramatic impacts on the livelihoods and food security of farmers who remain reliant on rain-fed agriculture (FAO 2006, 2007). Poverty, food, nutrition and water insecurity and environmental degradation characterize arid Southern Africa, including Zimbabwe (Wani et al., 2009). Shocks to an agricultural household/community can largely be looked at as weather-related and idiosyncratic (Hoogeveen 2002; Barrett et al., 2006). While the former hits a particular community as a whole, the latter allows the affected families to get relief from friends and relatives as not everyone suffers at the same time. Idiosyncratic shocks are thus easier to recover from. Furthermore, in the current address of vulnerability, besides natural calamities, socio-economic and political systems have been considered as major factors which make people vulnerable (Wisner, et al., 2004). The Disaster, Pressure and Release Model and Access Model developed by Wisner et al. (2004) are among the common and widely employed approaches in vulnerability analysis and emphasised that disaster is primarily the result of human actions rather than the natural factors which only have a triggering role. The study unpacks if the growing of small grains improved seed varieties and if practising conservation agriculture promoted resilience to farmers exposed to natural shocks, such as drought.

The Sustainable Livelihood Framework (SLF) indicates that the livelihood of a given household/state is dependent on its asset endowments- mainly Human Capital, Social Capital, Physical Capital, Financial Capital and Natural Capital- which together enable households to pursue a sustainable livelihood (Ndlovu et al., 2020). These capitals were derived from the Sustainable Livelihood Framework by various studies (DFID 1999; Keil et al., 2008; O'Mahony and Samek, 2016). The above forms of capital were used as exploratory variables in the research districts (Binga, Chiredzi, Hwange, Matobo). The differences in resource endowment and capitals across districts provide a rationale for the assessment of the resilience and welfare of smallholder, small grain farmers in different districts. Other studies (Sallu et al., 2010; Mpandeli and Maponya, 2014; Adu et al., 2018; Muthelo et al., 2019) have incorporated these capitals as explanatory variables for smallholder farmers' choices of climate change adaptation strategies.

Despite the hot climatic conditions of the districts, agriculture remains the main source of livelihoods in semi-arid regions of Zimbabwe, as postulated by Mugiya and Hofisi (2017). Just like all areas in Zimbabwe, the main crop grown by smallholder farmers in the study areas (Binga, Chiredzi, Hwange, Matobo) is maize. Droughts and little rainfall in the districts have led to low maize crop yields leading to high food insecurity in the areas. According to ZimVAC report (2019), food insecurity levels per district were as follows Binga 85.1%, Hwange 73.4%, Chiredzi 56.5% and Matobo 44.9%, hence the need for adaptation and mitigation measures in smallholder farming areas (ZimVAC, 2020). However, one of the most recommended approaches is the growing of drought-tolerant crops, such as small grains (Gukurume 2013; Musara et al. 2019; Muzerengi and Tirivangasi, 2019). Small grain crops like millet and sorghum, which can better withstand drought conditions and offer more stable yields in the long term, are a better choice in climate change adaptation (ICRISAT 2015; Nciizah et al., 2021). Farmers' ability to acknowledge the importance of adapting, therefore, largely depends on whether they have observed that there is climate change in the first place (Nciizah, 2019). Most studies have shown that farmers who perceive climate variability in line with the actual climate change records are most likely to adapt to climate change (Jiri et al., 2015). Numerous studies have been done on farmers' awareness of climate change (Gbetibouo, 2009; Okonya et al., 2013).

Focusing on Zimbabwe, it was apparent that it was not immune to trends in global erratic weather patterns exacerbated by worsening climate change (Mathew, 2015; UNDP, 2018; Muchuru and Nhamo, 2019). Climate change is one of the major threats faced by smallholder farmers, particularly in rural areas where the majority of Zimbabwe's population (67%) lives. Their livelihoods depend on agriculture (Moyo and Akpan, 2018). Our analysis of the reviewed studies was that despite the numerous studies on farmer resilience, policies that were informed by findings from these studies have not managed to address the problem of low adoption of improved varieties, weak market linkages leading to smallholder farmer vulnerabilities in Zimbabwe's low rainfall regions IV and V. We noted with concern that most of the studies we reviewed were conducted from countries other than Zimbabwe. Given the complexity of farmer resilience, its context specificity and its perceptual subjectivity, we considered that findings from the reviewed literature remain inconclusive. Hence, their findings were not expected to explain the vulnerability of smallholder, small grain farmers in our four case study sites. This triggered us to conduct this study which documented the specific obstacles which undermined the smallholder, small grain farmer vulnerability and resilience in regions IV and V of Zimbabwe.

3 Methodology

The study used a cross-sectional research design to focus on four (4) districts: Binga, Chiredzi, Hwange and Matobo, in agro-regions IV and V in Zimbabwe. Data were collected from primary and secondary sources using documentary analysis, face-to-face interviews, observations, structured and semi-structured questionnaires and focus group discussions (FGDs). Probability and non-probability sampling techniques were used to come up with a sample of 281 participants, comprising smallholder small grain farmers, government ministries, local leadership, seed breeders, and contractors (Ingwebu Breweries, Delta, Tongaat Hullets and Reapers). Both Multi-stage and Random sampling were employed in two (2) districts (Hwange and Matobo) that were not engaged in contract farming. Two wards per district and four villages (two villages per ward) were randomly selected. The study employed simple random sampling to identify farmers who were growing either or both small grain crops. For farmers that were into contract farming (Binga and Chiredzi) non-probability/convenient sampling was carried out. Simple random purposive sampling was employed for districts engaged with contract farming. We conducted eight (8) focus group discussions, 2 per district. Stratified random sampling was used on value chain actors (Ministry of Agriculture, Seed breeders and Input suppliers). Convenience and judgmental sampling were used to select local leadership that were from sampled villages**.** A representative sample was randomly selected with a specific sample size per district calculated proportionally as follows: Binga-60, Chiredzi-95, Hwange-72 and Matobo-54, giving a total of 281 farmers.

A statistical package, Stata version 16 was used to analyse household data and to present information on farmer resilience for the smallholder, small grain farmers. Thematic analyses were used for qualitative data where research themes and patterns from recorded immediate thoughts, reactions and interpretations were identified and captured during data collection.

3.1 Variable description

This section outlines the variables (Table 1) and analytical methods used in the vulnerability and resilience estimation.

3.2. Vulnerability Analysis

A total of 42 variables (Table 2 on appendix 2) have been selected for a Principal Component Analysis (PCA) model with orthogonal rotation (varimax) for easy interpretation. Factor analysis using PCA model was used for variable reduction and calculation of weights in characterizing both the vulnerability and resilience of small grain smallholder farmers in the region. A PCA method of factor analysis for identifying contributory factors or components that may shape the households' adaptive response against adverse impacts of climate change was used.

Table 1.
Summary Dimensions and indicators to measure Livelihood and Vulnerability Index (LVI)
(For more detailed information see table A1 in Appendix 1)

Factor	Description	Expected sign	Capital assets*
Food 1-8	Consumption food index	Negative	HC
Knowledge & Skills	Capacity building and advice	Negative	HC
Access to information	Communication channels	Positive	HC
Perceived climate changes	Changes in frequency of drought, rainfall, floods, start and end of rain season	Negative	NC
Adaptation measures	Adaptation measures to cope with climate change	Positive	HC
Crop production	Arable land, pre and post-harvest losses	Negative	PC
Demographics	Productive versus unproductive members and household size	Negative/Positive	SC
Livelihoods	Household income sources	Negative	EC

**HC-Human capital, NC-Natural capital, PC-Physical capital, SC-Social capital, EC-Economic capital.*
Source: Author compiled (2021)

In the PCA, the Kaiser-Meyer-Olkin measure has verified the sampling adequacy for the analysis with a value of 0.578 which is above the acceptable limit of 0.5. In addition, the Bartlett's test of sphericity demonstrates significance at $P<0.0001$, indicating that correlations between items are sufficiently significant for PCA and the average communality is >0.50. Based on this, factor analysis was considered valid. Five components with eigen values greater than 1 have been retained following the Kaiser criterion. Collectively, these five components accounted for 68.62% of the variance in the original 42 variables included in the analysis. The main principal components are summarised in Table 3. The first principal component (PC1) termed "human capital" constitutes 14 variables and explains 27.32% of variance. The second set PC2 (natural capital) constitutes 6 variables and explains 18.35% variance. The third PC3 (physical capital) constitutes 7 variables and explains 11.34% of variation. The fourth PC4 implies social capital which constitutes 7 variables and explains 6.61% of variation. The last component (PC5) termed economic capital constitutes 7 variables and explains 5.21% of the variation. All these components have links with household vulnerability and resilience to climate change. Based on PCA, the study allocated weights according to the percentage variance explained by each indicator in the calculation of Agricultural drought resilience indices (ADRI).

Table 2.
Summary Factor loadings of vulnerability and resilience on five components
(For more details see table A2 in Appendix 2)

Principal Component	PC1	PC2	PC3	PC4	PC5
Human capital	0.289				
Natural capital		0.611			
Physical capital			0.424		
Social capital				0.434	
Economic capital					0.019
Eigen value	3.927	2.945	2.448	1.589	1.489
Variance (%)	27.32	18.35	11.34	6.61	5.21
Cumulative variance (%)	27.32	45.67	57.01	63.62	68.62

Comment: If factor loadings were less than or equal modulus 0.3, they were omitted from the table
Source: Primary data (2021)

3.21 *Variable Description for Vulnerability and Resilience*

Five resilience and vulnerability indicators consisting of human capital (HC), social capital (SC), economic capital (EC), physical capital (PC) and natural capital (NC) were identified. Table 4 below shows variable description and the expected relationship with vulnerability and resilience. The human capital measured in this study related to food, access to information, knowledge, skills and other farmer characteristics relevant to small grain farming. The social capital comprised variables relating to the farmers' social networks, such as membership in a farmers' group and socio-demographic characteristics. Physical capital comprised all livelihood strategies. The economic capital comprised all financial resources and farmers' productive assets such as tractors, radio, draught power and livestock. Finally, the natural capital comprised natural vulnerability and climate variability that were self-reported by the farmers.

3.22 Calculating the Livelihood Economic Indicator

The Livelihood Economic Indicator is derived from the Sustainable Livelihood Framework (SLF) that identifies five different types of vulnerability indicators or capitals: Natural, Human, Physical, Social and Economic capitals (Table 3). The vulnerability indicator can help identify and target vulnerable regions and sectors of the populations, raise awareness and be part of the monitoring strategy. It also provides a household-based composite index. To calculate the LEI, the study used the major components and their values from the Livelihood Vulnerability Index (LVI) to calculate the scores for each type of capital asset by combining them as shown below and using the following formula:

$$Cv = \frac{\sum_{i=1}^{5} L_i}{n}$$

Where Cv is the value for each capital of LEI, L_i is the score for effect dimension for capital I, and n is the number of sub-dimensions forming a capital. LEI is then computed as the average of all capitals using the formula:

$$LEI = \frac{\sum_{i=1}^{5} W_i Cv_i}{\sum W_i}$$

Where Cv_i is the value of capital I, and W_i the weight of each capital, decided by the number of dimensions in each indicator. The LEI range is from 0 (least affected) to 1(most affected).

Table 3.
Indicators and effect dimensions of LEI

Indicator	Effect Dimensions
Human capital	Food
	Knowledge and skills
	Access to information
Natural capital	Natural vulnerability and climate variability
Social capital	Social-demographics
	Social networks
Economic capital	Finances and productive assets
Physical capital	Livelihood strategies

Source: Primary data (2021)

3.23 Household-level Analysis of the Data

Data obtained from the household survey was analysed by applying the Livelihoods Economic Indicator (LEI) and using descriptive statistics. LEI was the method of choice because it provides a household-based composite index, and it was applied to every household in this sample. LEI follows the sustainable rural livelihood structure of five types of capital that break into a series of sub-components. The results were then classified based on frequency (Table 5). For the frequency, intervals of 0.05 were arbitrarily chosen, and then households were grouped into four types of vulnerability: low, medium, high and very high. After classifying the sample by district, the average value for every sub-component was computed.

3.3 Resilience Analysis

The calculation of the agricultural drought resilience indices followed the resilience framework and scale by Walsh-Dilley et al. (2013). According to Walsh-Dilley, the resilience framework focuses on understanding and promoting the capacity of local communities to respond, negotiate and transform shocks, such that disturbances can initiate a downward spiral and may even provide opportunities for improvement. Based on PCA, we allocated weights according to the percentage variance explained by each indicator. Five resilience indicators consisting of human, physical, social, economic and natural capital were identified. Each resilience capital was calculated as the summation of indicators defining the capitals by their respective weights generated from the PCA and specified as:

$$RI = \sum_{c=1}^{S} w_g t_i * indicators$$

RI denotes the individual resilience capital index for V [(human capital (HC), social capital (SC), economic capital (EC), physical capital (PC) and natural capital (NC) and w_g denotes the weight for each indicator for a given capital ($w_1 = 0.2732; w_2 = 0.1835; w_3 = 0.1134; w_4 = 0.0661; w_5 = 0.0521$). The variables defining each capital are represented by indicators. The total ADRI was the summation of the HC, PC SC, EC and NC computed by the equation above.

4 Results and Discussion

This study collected data from 281 participants drawn from four districts (Binga, Hwange, Matobo & Chiredzi) in agro-regions IV and V in Zimbabwe, to explore how climate change impacts farmers and how the sampled households have become resilient to these stresses.

4.1 Adaptation strategies used by smallholder, small grain farmers

Smallholder farmers in the study area have, in many cases, adapted their farming to climate change and variability. They have built a strong indigenous knowledge of their areas to secure their livelihoods. An analysis of the adaptation strategies used to deal with major climate extremes shows that farmers use different strategies for different shocks. Climate change has caused a lot of stress and shocks in communities. This has not spared the smallholder, small grain farmers in Zimbabwe. These stresses and shocks have left farmers in vulnerable situations. However, farmers have their coping mechanisms to bounce back (resilience) from these situations. These coping mechanisms include small grain production, conservation agriculture, crop diversification, livestock production, gold panning and vegetable production. The adaptation strategies are meant to move farmers from vulnerability to resilience. Smallholder, small grain farmers use a number of livelihood strategies that are discussed in the sections that follow. Some of the adopted and recommended adaptation strategies are presented in sub-sections below.

4.11 Livestock Ownership

A higher number of smallholder farmers had a high number of livestock such as cattle, goats and chickens. This concurs with Ugochukwu (2020) who reported that logic assumes that the larger number of livestock owned, the more likely farmers will participate in markets, either to sell stock or acquire necessary inputs, such as drugs or supplements. The average number of cattle each household had from the smallholder, small grain farmers was eight, which is above the national average. ZIMVAC (2022) reported that the national average herd of cattle is five. Farmers can sell the animals in case of shocks. This is an indication that farmers have assets that can be used to hedge against climate change.

4.12 Household Income Sources

Sampled households obtained income from a variety of sources. Vegetables, livestock, field crops and gold mining were the major sources of household income. Farmers were asked to rank income sources in order of importance. Livestock, field crops, vegetables and gold mining were ranked number one and the most important? which shows the importance of crop and livestock production as well as artisanal mining in household income generation (Figure 1).

4.1.3 Changes in Rainfall

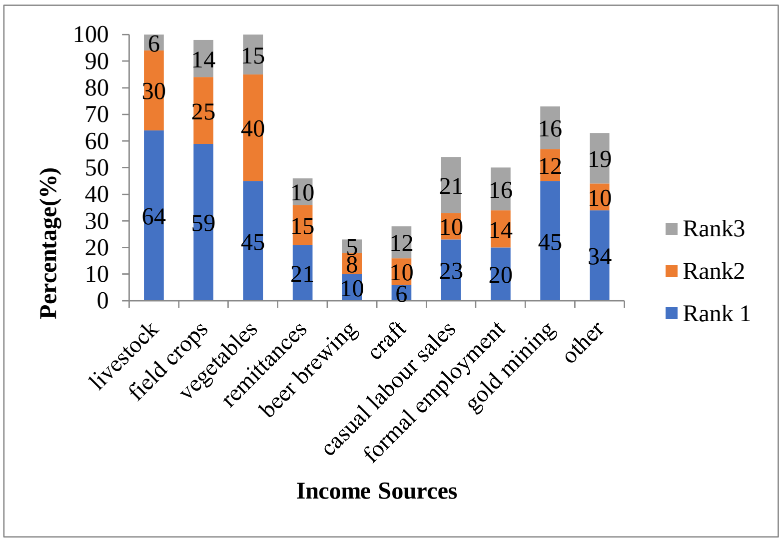
Of the (95%, n=281) farmers sampled in the study on perceiving changes in rainfall, the most adopted strategies (Fig 2) were: planting of drought-tolerant varieties (70%), increasing area under small grain (79%), reducing area under maize (42%) and use of conservation agriculture (62%).

4.1.4 Changes in Drought Frequency

A high perception of drought occurrence has been noticed by the farmers over the past 5 years. In trying to mitigate the effects of drought, farmers have adopted a number of measures as shown on Fig 3 below. The most commonly adopted measures in response to drought occurrence were: increasing area under small grain (87%), planting of drought-resistant varieties (82), conservation agriculture (76%), and planting of short season varieties (75%).

Generally, for all climatic changes, the majority of farmers increased area under small grain, followed by growing other drought-tolerant crops. Most farmers in Binga (83%) and Chiredzi (80%) adopted this measure. In support of the findings, other studies (Gukurume, 2013; Musara et al., 2019; Muzerengi and Tirivangasi, 2019) reported that the most recommended approach in areas affected by climate change is the growing of drought-tolerant crops, such as small grains. Adoption of small grains becomes a critical requirement that must be embraced by households in semi-arid regions. Furthermore, these small grains have become favoured because of their good adaptation to hard environments and their good yield of production (Musara et al., 2019). Similarly, Orr et al. (2016) reported that small grains are genetically adapted to dry lands that face little and irregular rainfall, drought and high temperatures than other cereals like maize. In support of the above studies, Muzerengi and Tirivangasi (2019) found that small grains are able to give some yields in years of low rainfall, especially when grown in a multi-cropped system, whereas maize will be a complete failure.

This is consistent with similar studies that reported that small grain crops like millet and sorghum, can better withstand drought conditions and offer more stable yields in the long term, are a better choice in climate change adaptation (ICRISAT 2015; Nciizah et al., 2021). Furthermore, ICRISAT (2015) found that small grains adapt well to harsh climates and thus can grow in dry conditions due to their ability to tolerate heat, salt and water stress, which makes them an ideal crop for semi-arid areas. This is supported by Musara and Musemwa (2020) who reported that the allocation of more land towards improved sorghum varieties by smallholder farmers resulted in improved food diversity and food access, as these crops were more likely to be more resilient to high temperatures and low rainfall conditions due to climate change. All in all, the study has found that small grains are a good adaptive strategy when farmers are faced with stresses and shocks induced by climate change. In the same vein, small grains promote food security in drought-prone areas, hence a resilient building strategy.



Other=carpentry, builder, faith healer, money clubs

Figure 1. Percentage distribution of ranked sources of income for sampled households (Source: Primary data (2021))

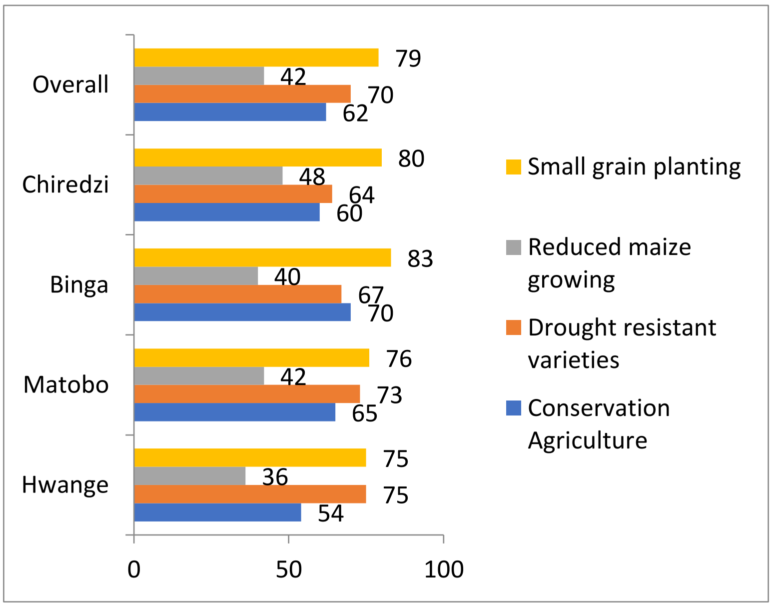


Figure 2. Percentage distribution of adopted strategies in response to rainfall changes by district.
Source: Primary data (2021)

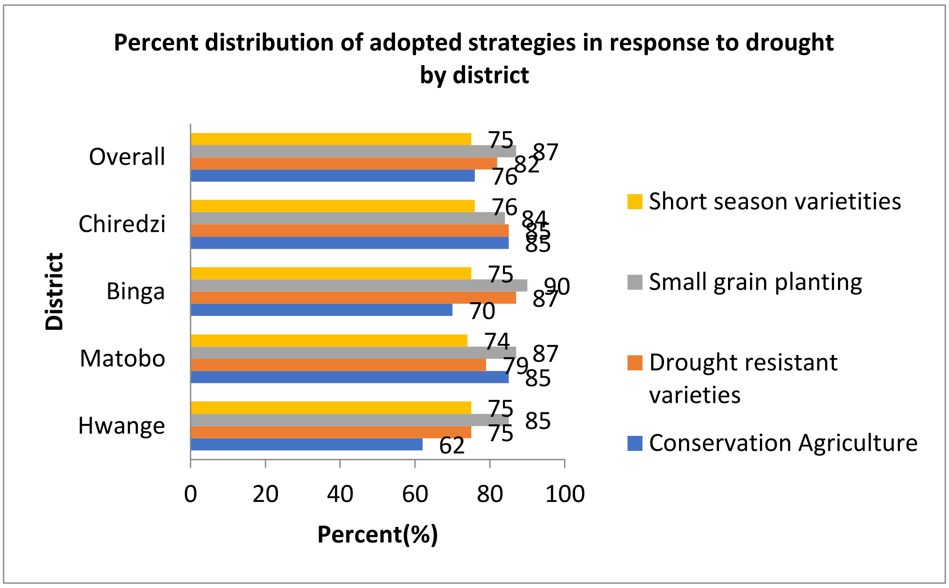


Figure 3. Percentage distribution of adopted strategies in response to drought by district
Source: Primary data (2021)

4.2 Vulnerability analysis

4.21 Livelihood Economic Indicators

The economic capital, which includes finances and productive assets, is the most influential to the vulnerability index and has the most effect on a household with a value of 0. 776 (Table 4). Among the indicators used to measure financial capital, those with the highest PCA result make a significant difference among individuals who have financial service and savings accounts in formal financial institutions, have income from non-agricultural sources and wealth status. A study by Mekonnen et al. (2019), reported a similar result where the extent of vulnerability of households with diversified sources of income were found to be less as compared with their counterparts. Adding their dependence on farming, this can provoke large economic instabilities, such as crop losses, education costs and large accumulation of debts, among other problems. This is supported by Briguglio and Galea (2003) who reported that the inherent aspect of resilience may be considered as the obverse of vulnerability, in the sense that countries that inherently lack economic resilience are economically vulnerable. Furthermore, economic capacity would play a vital role in building the adaptive capacity of smallholder farmers to the adverse impacts of climate change (Asfaw et al., 2021).

In this study, the social capital is the least for household vulnerability with a value of 0.348, having a low effect due to good social networks and good socio-demographic profiles. The population helps each other during times of need and 58% of the sampled households were affiliated to farming groups that help in the development of the household and community. In support of the study by Ashaw et al. (2021) better social capital could be due to more exposure of the communities to climate-related problems which demanded the collective action of the people. In this study, farmers were put in production groups so their combined yields would meet the requirements of the contract, so they would not loose in the market. Dependence ratio and household size are moderately low, which facilitates household development. The sampled households are generally old, which means they might have experience in agriculture and coping mechanisms which help the families to be less vulnerable.

Table 4:
Variations in vulnerability per indicator

Factor	Major components	Subcomponents number	Indicator value
Human capital	Food	8	0.506
	Knowledge and skills and access to information	5	0.632
Social capital	Social demographic and social networks	7	0.348
Economic capital	Finances and productive assets	6	0.776
Physical capital	Livelihood strategies	7	0.523
Natural capital	Natural vulnerability and climate variability	6	0.587

Source: Primary data (2021)

To further understand the dimensions of the livelihood's indicator value of the farmers, the study disaggregated the vulnerability by different capitals as shown on Figure 4 below.

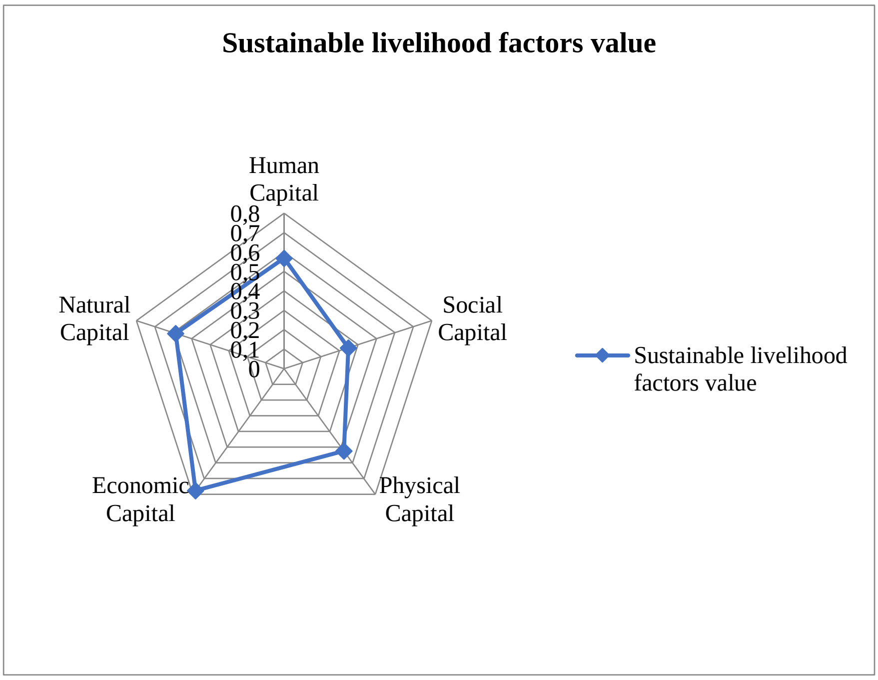


Figure 4. Vulnerability radar of five capitals for the Livelihood Economic Indicator
Source: Primary data (2021)

4.22 Household Level Vulnerability

After applying the LEI for every individual household and analysing the data, we classified households according to their relative vulnerability as shown in Table 5. About 46.3% of the sampled households were in the medium vulnerability group, while 26% were in the highly vulnerable group. Only 10.3% were in the very vulnerable group and 17.4% were in the low vulnerable group. Households varied in their vulnerability index. This is consistent with other studies (IPCC, 2014; Coulibaly et al., 2015) that reported that people vary in their vulnerability (exposure) at the household level. However, when aggregated by the district, most sampled households in Hwange and Matobo were more vulnerable to the effects of drought. Based on field observation, farmers in Hwange and Matobo did not have a reliable market to sell their produce compared to other districts which had reliable contractors. Those who managed to sell, were selling to individuals and the majority had low land holdings. These two districts had small land holdings as they did not have motivation to extend their land holdings. The study is supported by Matter et al. (2021) who found that the assessment of individual components and food insecurity also showed that those households with smaller land plots and with less livestock had higher risk of suffering food insecurity. Boillat et al. (2019) suggested that the availability of larger land plots allows a true crop rotation, which increases the chance of meeting yield thresholds, particularly under dry conditions. Results of the study show that farmers in Binga and Chiredzi were less vulnerable. These two districts had high land holdings and high ownership of productive assets such as tractors, ploughs, threshers and cars. Reliable market and access to credit through contractors motivated them to produce more.

4.3 Resilience Analysis

Resilience varied with districts, with Chiredzi (4.56) being the highest and Matobo the lowest (3.32) as shown in Table 6. The smallholder farmers' own livelihood capitals played a significant role in improving their resilience and welfare. The study identified five key capitals that define the agricultural drought resilience level of smallholder farmers and their welfare gains. The study found that the smallholder, small grain farmers were, to some extent, resilient to agricultural drought. It was revealed that the level of resilience varied according to how the smallholder, small grain farmer was endowed with human, social, physical, economic and natural capitals.

Table 5.
Percentage distribution of vulnerability in the sampled households by district

Vulnerability groups	Total (%)	Binga	Chiredzi	Hwange	Matobo
Low	49(17.4)	6(10.0)	8(8.4)	19(26.4)	16(29.6)
Medium	130(46.3)	35(58.3)	64(67.4)	17(23.6)	14(25.9)
High	73(26.0)	16(26.7)	19(20)	28(38.9)	10(18.5)
Very high	29(10.3)	3(5)	4(4.2)	8(11.1)	14(25.9)
Total	**281(100)**	**60(100)**	**95(100)**	**72(100)**	**54(100)**

Source: Primary data (2021)

Table 6.
Overall ADRI and ADRI indices by district

District	Total	ADRI Mean	SD
Binga	60	4.38	1.35
Hwange	72	3.89	1.20
Chiredzi	95	4.56	2.11
Matobo	54	3.32	1.92
Overall	**281**	**4.04**	**1.74**

Source: Primary data (2021)

The study was supported by Matlou et al. (2021) who reported that the differences in resource endowment and capitals across districts provide a rationale for the assessment of the resilience and welfare of smallholder farmers in different districts. The four districts, overall Agriculture Drought Resilience Index (ADRI) was 4.04 which indicates that the farmers were above average in terms of resilience. This could be attributed to the fact that, generally, the whole country, including the study areas, received good rains resulting in improved yields compared to the previous years. Furthermore, the districts had multiple coping mechanisms (small grain production, livestock, drought tolerant crops, gold panning) that contributed to a higher resilience score.

To further understand the dimensions of the ADRI of the farmers, the study disaggregated the resilience by different capitals as shown on Figure 5.

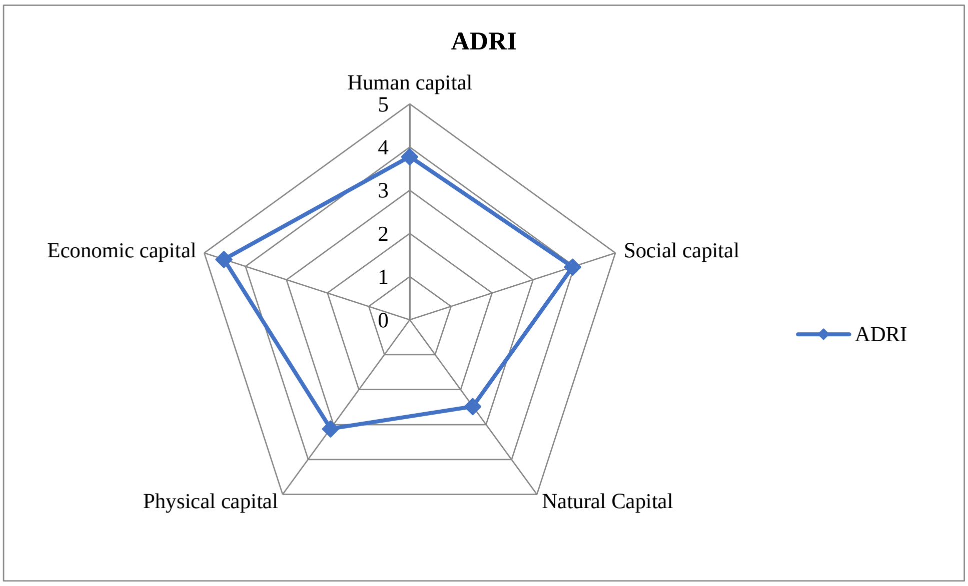


Figure 5. Agricultural Drought Resilience Index values for each capital
Source: Primary data (2021)

The economic resilience capital was the highest with an index of 4.52, suggesting that farmers had good production resources and assets that could have helped them absorb climatic shocks. The economic capital was computed from ownership of agricultural assets (e.g. ox-drawn plough, hand hoes, draught power), credit access, value of livestock and crops. Seventy-nine percent owned ox-drawn ploughs, 68% draught power, 92.5% chickens and 57% small hand farm implements such as ploughs, hand hoes, knapsack and sprayers. This may allow farmers to re-invest their incomes in higher quality farming inputs and enhance their ability to counter the impacts of weather shocks. This is supported by Matter et al. (2021) who reported that households benefitting from a diversified income portfolio are not only more protected against production loss and other risks; they also tend to have more stable incomes. This may allow farmers to re-invest their incomes in higher quality farming inputs and enhance their ability to counter the impacts of weather shocks (Wan et al., 2016).

Similarly, the study by Maltou and Bahta (2019) noted that through the use of capitals, farming households with access to credit and training and were part of a co-operative proved to be more resilient to agricultural drought than those who had no access to these variables. Farmers indicated selling goats, chickens and cattle during the drought season. Some farmers had multiple sources of income such as gold panning, selling vegetables and field crops, as well as selling livestock during the drought season. The study measured livelihoods through the ownership of livestock, remittances, small grain production levels and other economic levels. The study is supported with the findings by Sikwela and Mushunje (2013) who indicated that farmers' livelihoods have a significant and positive impact on smallholder farmers' resilience. Furthermore, the study is in line with a study by Maltou and Bahta (2019), who found that farming households with access to credit, livestock and training proved to be more resilient to agricultural drought than those without access to these variables.

The social resilience capital was the second, with an index of 3.96. The social capital was computed from social demographic characteristics and social networks. Furthermore, the social capital demonstrated that smallholder, small grain farmers had strong social networks, such as farmers' associations, access to extension services, families and friends, which offered them support in times of drought. Similarly, Mukhovi et al. (2020) reported that social capital allows farmers to exchange ideas and resources to address the many challenges they face. Furthermore, social groups benefit farmers through farm labour participation as self-help groups organise themselves to work on each other's farms, thereby addressing labour shortage (Ifejika Speranza et al., 2008).

The third highest resilience capital was related to human capital available to the farmer, with an index of 3.78. The human capital was computed from food coping strategies, access to information, knowledge and skills, adaptive capacity that could assist on the farm and knowledge of drought. The fourth resilience capital was related to physical capital, with an index of 3.12**.** The vast majority of farmers indicated harvest losses due to birds and rodents which reduced the food availability for the family. There were agriculture problems recorded in other districts such as certified seed and fertilizer affordability issues, low extension contacts and poor grain market prices preventing high crop yields and thus not achieving maximum profit. Most of the farmers depend solely on agriculture as a source of income which increases their vulnerability. On the Agricultural diversification index, the total cultivated land has low values in most districts, especially those in Hwange and Matobo, contributing to a decrease in the physical capital index.

The lowest resilience capital was related to natural resources, with an index of 2.48, which suggests that farmers were vulnerable when it comes to natural resources. The low natural capital could also have been caused by poor soils which ranged from sandy soils to sandy loam as tested by (ICRISAT, 2021). The smallholder, small grain farmers had low natural resource endowments and hence had low natural resilience capital. This was not surprising, considering that most livestock farmers did not have access to reliable water, land and pastures, particularly in a time of drought. The strength of the livelihood capitals in enhancing the resilience of smallholder farmers in this study for the Southern Zimbabwe (Binga, Chiredzi, Hwange, Matobo) were similar to what Muthelo et al. (2019) found for smallholder livestock farmers in the Free State Province of South Africa. They found that smallholder farmers have a high economic resilience capital followed by social, natural and human capitals.

Overall, the district with highest resilience was Chiredzi followed by Binga, then Hwange and lastly, Matobo. As vulnerability is the other side of the coin of resilience, when one is vulnerable, he/she cannot be resilient. When comparing vulnerability and resilience across districts, the district with low vulnerability had high resilience and vice versa. This gives confidence in our results. Employing a diversity of agricultural techniques also improved food security, which is likely an indirect result of enhanced yields. Indeed, higher small grain yields are correlated with higher food security. Moreover, higher income diversity was also related to improved yields. Besides the resilience capitals, the findings further indicate that livestock ownership, small grain production, vegetable production and gold panning improved the resilience of smallholder farmers in the study area.

5. Summary of Findings and Conclusion

The success of the development of the small grain value chain that fully integrates smallholder, small grain farmers' concerns will depend on the policy environment and the institutional framework within which the value chain develops. There have been some efforts and strategies that have promoted the involvement of smallholder, small grain farmers in the small grain value chain. The efforts have met with limited success, partly because policies in place have not adequately promoted effective participation of smallholder, small grain farmers in the small grain value chain because of a lack of framework or strategy for supporting farmers' empowerment. Consequently, there has been a piecemeal approach to the small grain value chain development that incorporates smallholder, small grain farmers' concerns. While the Ministry of Agriculture has developed a smallholder strategy for the agricultural sector, it does not seem to have any links between this strategy and the other value chain nodes that are outside its mandate. Value chain development requires that strong linkages be forged between the producers, public sector (other government ministries) and private sector. Currently, there is no framework that links these ministries to develop a well-integrated small grain value chain. Results show that there is no policy that is inclined to small grain value chains, from input supply all the way to the marketing of the grain. Policy inclined to small grain production is still in draft stage. If these are promoted, no doubt, higher yields will be improved leading to food and nutrition security. This will in turn ensure that farmers are resilient.

The adaptation strategies used by smallholder, small grain farmers to promote resilience were the ownership of productive assets, increasing area under small grain, followed by the growing of other drought-tolerant crops. Farmer resilience varied with location, with Chiredzi being the highest and Matobo the lowest in terms of the agriculture drought index. Districts under contract farming were more resilient than those which were not. Overall, the district with the highest resilience was Chiredzi (4.56), followed by Binga (4.38), then Hwange (3.89) and lastly, Matobo ((3.32). As vulnerability is the other side of the coin of resilience, when one is vulnerable, he/she cannot be resilient. When comparing vulnerability and resilience across districts, the district with low vulnerability had high resilience and vice versa. Districts that are not under contract farming are more vulnerable than their counterparts despite growing small grains as a resilience-building strategy. There is no policy that supports small grain production in Zimbabwe.

The policy implications of our study are that agricultural policies relating to the production of small grain on contract farming must be aggressively enforced by government based on science. Another profound implication is that it contributed to the existing body of literature by extending previous scholarship that focused on small grain farmer resilience. Furthermore, our findings provide insight on tangible obstacles that contribute towards the hesitancy to adopt contract farming by smallholder farmers in arid regions. Last but equally important, our study provided context-specific findings from data drawn from the people who had real life experiences about the studied phenomenon. The data they provided were based on lived experiences rather than abstract hypotheses.

Farmers in regions IV and V should embrace the production of improved small grain varieties and practice conservation agriculture as an adaptation strategy to climate change. Based on our study findings, we recommend that since farmers who were more resilient had a number of livelihoods activities, there is need to craft a policy that promotes diversification. The government needs to support indigenous knowledge that farmers can use to bounce back when a disaster strikes. The policy to enforce disaster preparedness plans from national level all the way to the farmer must be enacted. Disaster risk reduction (DRR) committees should be mandatory so as to share information on climate variability. Since low access to credit, information and education was correlated to vulnerability, there is need to craft a policy that supports access to credit and information.

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Appendix

Table A1.
Dimensions and indicators to measure Livelihood and Vulnerability Index (LVI)

Factor	Description	Expected sign	Capital assets*
Food 1	Number of days household rely on less preferred and less expensive foods	Negative	HC
Food 2	Number of days household borrow food or rely on friends or relatives	Negative	HC
Food 3	Number of days the household limit portion size at meals	Negative	HC
Food 4	Number of days household restrict consumption by adults in order for small children to eat	Negative	HC
Food 5	Number of days household reduce number of meals eaten in a day	Negative	HC
Food 6	Percentage of household who sold household assets or goods to buy food	Negative	HC
Food 7	Percentage of household who have to reduce non-food expenses on health (including drugs) to buy food	Negative	HC
Food 8	Crop Diversity Index=1/number of crops grown by a household +1	Negative	HC
Knowledge and skills 1	Did anyone in the household receive extension advice in the past 5 years	Negative	HC
Knowledge and skills 2	Did anyone receive training on climate change	Negative	HC
Access to information 1	Does the family own a TV	Positive	HC
Access to information 2	Does family own a radio	Positive	HC
Access to information 3	Does anyone own mobile phone?	Positive	HC
Perceived drought increase	Has the household reported change in frequency of droughts in the past 5 years	Negative	NC
Perceived rainfall increase	Has the household reported change in frequency of rainfall in the past 5 years	Negative	NC
Perceived flood increase	Has the household reported change in frequency of floods in the past 5 years	Negative	NC
Perceived decrease	Has the household reported change in start of rain season	Negative	NC
Perceived cessation of rainy season	Has the household reported change in cessation of rainy season in the past 5 years	Negative	NC
Perceived temperature increase	Has the household reported change in number of hot days in the past 5 years	Negative	NC
Adaptation measures	Do they take any adaption measures to cope with climate/weather related hazards	Positive	HC
Cultivated land	Total arable land in hectares	Positive	PC
Certified seed	Difficulty obtaining packed or treated small grain seed	Negative	PC
Failure to sell	Has the household reported failure to sell grain in the past 5 years	Negative	PC
Pre-harvest loss	Has the household reported pre-harvest loss in the past 5 years	Negative	PC
Harvest processing loss	Has the household reported losses during processing in the past 5 years	Negative	PC
Harvest storage losses	Has the household reported losses during harvest storage in the past 5 years	Negative	PC
Harvest handling losses	Has the household reported losses during handling harvest in the past 5 years	Negative	PC
Dependency ratio	Ratio of productive vs unproductive household members	Negative	SC
Gender	Is the household head female	Negative	SC
Household head age	Household head age	Positive/Negative	SC
Household size	Number of family members of the Household	Positive/Negative	SC
Membership in farming groups	Membership to farming groups	Positive	SC
Education	Number of years spent in school	Positive	SC
Marital status	Marital status of the head of household	Positive/Negative	SC
Expected market price	Did they get the expected price for the crop	Positive	EC
Dependency on agriculture	Does the household income depend solely on agriculture	Negative	EC
Access to credit	Household with access to credit	Positive/Negative	EC
Household income	Household sources of income other than agriculture	Positive	EC
Owning draught power	Percentage of household who do not own draught power	Negative	EC
Livestock owned	Percentage of household without livestock	Negative	EC
Ox-drawn plough	Percentage of household without ox-drawn plough	Negative	EC

**Comment: HC-Human capital, NC-Natural capital, PC-Physical capital, SC-Social capital, EC-Economic capital.*
Source: Author compiled (2021)

APPENDIX 2

Table A2.

Factor loadings of vulnerability and resilience on five components

Principal component	**PC1**	**PC2**	**PC3**	**PC4**	**PC5**
Human Capital					
Number of days household rely on less preferred and less expensive foods	**0.786**				
Number of days household borrow food or rely from friends or relatives	**0.767**				
Number of days the household limit portion size at meals	**-0.736**				
Number of days household restrict consumption by adults in order for small children to eat	**0.586**				
Number of days household reduce number of meals eaten in a day	**0.564**				
Percentage of household who sold household assets or goods to buy food	**0.578**				
Percentage of household who have to reduce non-food expenses on health (including drugs) to buy food	**-0.533**				
Crop Diversity Index=1/number of crops grown by a household +1	**0.532**				
Did anyone in the household receive extension advice in the past 5 years	**-0.534**				
Did anyone receive training on climate change	**0.423**				
Does the family own a TV	**0.342**				
Does family own a radio	**0.403**				
Does anyone own mobile phone?	**0.424**				
Do they take any adaption measures to cope with climate/weather related	**0.448**				
Natural capital					
Has the household reported change in frequency of droughts in the past 5 years		**0.831**			
Has the household reported change in frequency of rainfall in the past 5 years		**0.796**			
Has the household reported change in frequency of floods in the past 5 years		**0.652**			
Has the household reported change in start of rain season		**0.543**			
Has the household reported change in cessation of rainy season in the past 5 years		**0.432**			
Has the household reported change in number of hot days in the past 5 years		**0.412**			
Physical capital					
Total arable land in hectares			**0.753**		
Difficulty obtaining packed or treated small grain seed			**0.712**		
Has the household reported failure to sell grain in the past 5 years			**0.687**		
Has the household reported pre-harvest loss in the past 5 years			**0.458**		
Has the household reported losses during processing in the past 5 years			**0.441**		
Has the household reported losses during harvest storage loss in the past 5 years			**-0.401**		
Has the household reported losses during handling harvest in the past 5 years			**0.321**		
Social capital					
Ratio of productive vs unproductive household members				**0.892**	
Is the household head female				**0.768**	
Household head age				**0.723**	
Number of family members of the Household				**0.624**	
Membership to farming groups				**-0.603**	
Number of years spent in school				**0.323**	
Marital status of the head of household				**0.314**	
Economic capital					
Did they get the expected price for the crop					**0.845**
Does the household income depend solely on agriculture					**-0.764**
Household with access to credit					**-0.780**
Household sources of income other than agriculture					**-0.721**
Percentage of household who do not own draught power					**0.578**
Percentage of household without livestock					**0.520**
Percentage of household without ox-drawn plough					**0.457**
Eigen value	**3.923**	**2.945**	**2.448**	**1.589**	**1.489**
Variance (%)	**27.32**	**18.35**	**11.34**	**6.61**	**5.21**
Cumulative variance (%)	**27.32**	**45.67**	**57.01**	**63.62**	**68.62**

Comment: If factor loadings were less than or equal modulus 0.3, it was omitted from the table
Source: Primary data (2021)