Livelihood Impact and Risk Management of Drought: The Experiences of Farming Households in the Free State Province, South Africa

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Research Article

Keywords: Drought-risk management, Seemingly unrelated regression, Perceived impact, Thaba Nchu

Posted Date: May 24th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-429190/v1

Livelihood Impact and Risk Management of Drought: The Experiences of Farming Households in the Free State Province, South Africa

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Abstract

Drought is one of the main causes of food insecurity, malnutrition and poverty. It is therefore important to understand the perception of farmers on socioeconomic and environmental impacts of drought and the strategies employed to manage it. Using data collected from 301 smallholder households in Thaba Nchu, Free State Province, the study contributes to three perspectives: analysing the perceived socio-economic and environmental impact of drought, examining the determinants of the perceived impact, and identifying factors affecting the intensity of drought-risk management practices used by smallholder farming households. Using 11 indicators as a measure of perceived impact, the findings from the principal component analysis (PCA) revealed three main dimensions of perceived drought impact: economic, environmental and social impacts. Different socio-economic and institutional factors have a different influence on the three dimensions. In addition, factors such as age, household size, non-farm work and extension services are significant in determining the intensity of drought-risk management strategies implemented by farmers in the study area. The study therefore recommends that climate risk management be integrated into the provision of extension services, particularly in drought-prone areas such as the Free State Province. Encouraging farmers to engage in non-agricultural economic activities is also crucial, as this can serve as insurance against events such as drought.

Keywords: *Drought-risk management; Seemingly unrelated regression; Perceived impact; Thaba Nchu.*

Introduction

The evidence of climate change is real, and its impacts is felt all over the world, with agricultural households in both developed and developing economies suffering the most (Wang, 2021). Agricultural production in sub-Saharan Africa (SSA) is highly dependent on weather patterns, particularly high temperatures and rainfall. With the rise in global temperature, inter-annual temperature and precipitation variability will also increase (Dai, 2013). For those whose livelihoods depends on agricultural activities, these irregular patterns of climate change pose serious difficulties (Linke et al., 2020). Intergovernmental Panel on Climate Change (IPCC 2014) indicated that "more frequent and/or longer heat waves and warms spells in Africa should be expected." Agriculture, the core use of land, is highly sensitive to extreme climate variations, and farmers are usually affected by the whims of climate change and variability (Shiferaw et al., 2014). Widely disparate weather and extreme climate variability poses the major challenge to smallholder farmers and limits their overall human development. (Hellmuth et al., 2009; Shiferaw et al., 2014). Rainfall is one of the climatic factors whose variability has a major impact on farmers' livelihoods, particularly the poor and marginalized, as a result of its impact on plants and livestock (Nanganga and Safalaoh, 2020).

Extreme variability in rainfall patterns leads to floods and droughts, leading to a reduction in GDP growth in many SSA countries (Kogo et al., 2020). Drought is considered to be the most devastating climate-related events in the world, causing serious damage to agricultural, environmental and socioeconomic activities (Moeletsi and Walker, 2012). Drought occurs when there is a lack of sufficient rainfall over a long period of time (usually months) leading to water shortages and adverse impacts on the lives of people, animals and the loss of vegetation (Msangi, 2004). Apart from a decrease in rainfall giving rise to drought, drought can also result from human activities such as a change in land use (Keesstra, 2007; Mohmmed et al., 2018).

Essentially, the occurrence of drought can be divided into four main factors, depending on the impact: agricultural, socioeconomics, meteorological and hydrological (Thilakarathne and Sridhar, 2017). The frequency and severity of droughts have increased significantly in recent years as a result of climate change and agricultural activities in developing economies such as Africa countries (Panthi et al., 2016).

South Africa has relatively less rainfall; therefore it is generally described as a semi-arid and water-stressed country (Botai et al., 2016). The average annual rainfall in the country is around 450mm, which is well below the global average of about 860mm per year. The country experiences seasonal rainfall variations, with most rainfall occurring during summer periods (usually November – March). However, most of the areas in eastern Highveld receive between 500mm and 900mm amount of rainfall per year while provinces such as Free State and Northwest receive less than 500mm of rainfall per year. This insufficient rainfall usually leads to drought, especially in those areas with less rainfall. Drought events in South Africa are common, occurring at different intensities in different parts of the country, and 2015 remains the driest year in the last 10 decades (South African Weather Services [SAWS], 2015). As a result, the rural smallholder farmers are most affected and the production systems are threatened by extreme weather conditions which cause thermal stress in plants and livestock (Maponya and Mpandeli, 2013). For example, drought is the main climate-related hazard in the Free State Province of South Africa, with the most devastating impact on farmers' crops and livestock (Botai et al., 2016). Botai et al. (2016) noted that frequency and severity of drought was more pronounced in Free State Province than in other parts of South Africa.

Smallholder farmers who are most affected by extreme weather conditions such as drought have long history of risk management techniques to mitigate the effects of the events. Drought Risk Management (DRM) can be defined as strategies put in place to mitigate adverse effects while trying to pursue positive objectives (Hansen et al. 2004). DRM is part of climate risk management techniques that refer to climate mitigation strategies decision-making, where farmers use the information they receive to take action to minimize climate risk and exploit climate opportunities (Hellmuth et al., 2009; Shiferaw et al., 2014). DRM tools can be divided into two: ex-ante DRM (coping mechanisms) and ex-post (adaptation mechanisms), depending on whether the strategy reduce risk exposure or minimize the impact of undesirable outcomes after the shock (Owens et al., 2003). More often than not, farmers dwelling in drought-prone areas modify their production systems such that the likely impacts of the shock could be minimized within acceptable level.

Ex-ante strategies are considered as consumption-smoothen tools as they help to reduce income fluctuations. There are two main ways of ex-ante coping strategies: diversification and application of flexible decision-making. Diversification involves a shift from mono-cropping to the planting of a broader plants /and rearing of livestock, and engagement in other non-farm income-generating activities (Asante et al., 2018; Bellon et al., 2020). Flexible decision-making is an adaptive approach that enable farming households to switch between farm activities to help combat risk of extreme conditions (Shiferaw et al., 2014). These include temporary adjusting the use farm resources based on climatic conditions and adjusting plant population. Farmers in SSA used other DRM strategies such as maintaining flexible decision-making (e.g., planting of drought-tolerant crops), irrigation/water harvesting, and insurance against drought effects (Bawakyillenuo et al., 2016; Williams et al., 2019). Agricultural households also employ ex-post DRM strategies to avoid the reduction of consumption expenditure below certain threshold as a result of climatic shocks. Depending on how serious the shock may be, farming households employ varied range of ex-post DRM strategies such as liquidation of farm assets (e.g., land, livestock, etc.), and reduction of consumption, particularly on non-essential items (e.g., clothing, social functions, etc.). Households, sometimes also rely on insurance schemes, public relief and safety net programs (interevention from government and NGOs). Smallholder farmers can not handle or cope with the situation during drought periods without external assistance from governmental and non-governmental agencies (South African Government Gazette 2005). Dryness can result in food scarcity and social unrest, and land distribution can become stagnant. Drought has forced farmers in many areas to sell some of their livestock in order to buy fodder for the rest (Mudombi 2011). Hence, the importance of insurance, safety-nets and government relief packages. Irrespective of the measures put in place by farmers or an agency to mitigate the effects of the shocks, how farmers perceived the impact of drought is key to facilitate the support of policy-related DRM strategies.

Perception and DRM strategies are the two significant elements in the process of adaptation. Farmers first need to perceived the impact of drought in order to help them take appropriate action to mitigate their vulnerability and build their adaptive capacity (Bryan et al., 2009). Misleading perceptions about the consequences of climate change and variability may lead to no action taken to manage the risk. However, farmers who perceive potential consequences of extreme weather conditions such as drought are more likely to take precautionary measures to minimize its effects and support programs that aims to address it (Niles et al., 2013). Drought impacts on smallholder farmers result from the interaction between natural events and the demand farmers place on the water supply. There are three impacts of droughts: economic, social and environmental. Economic impacts of drought have to do with the effects of drought on food security, malnutrition, food prices and reduction of household income. For example, in South Africa, many farming households experienced persistent food insecurity, malnutrition and reduction in income levels during extended period of drought. Thus, drought is an important factor in increasing food insecurity, and is strongly linked to periods of vulnerability as a result of climate stress. Food prices, particularly staples are usually high during the period of drought, which results in hunger and malnutrition, as the low-income group cannot afford the high prices of food. The social impact of drought refers to impact such as public safety, conflicts between water users, and reduced quality of life. One of the significant social impact is population migration. Those that migrate usually migrate to urban areas, or areas outside the drought regions. The migrants hardly ever return home, even when the drought is less intense, which results in the deprivation of valuable human resources in rural areas. The environmental impact of drought results in damage to air and water quality, plant and animal species, forest and range fires and wildlife habitats, degradation of landscape quality and loss of biodiversity. Some of the effects are short term, and conditions return to normal after or at the end of the drought period. Other environmental effects last for a long period of time, which may even result in them becoming permanent. The degradation of landscape quality may possibly lead to a more permanent loss of biological productivity (Wilhite and Vanyarkho 2000).

Many pieces of literature (Alam et al., 2017; Martey and Kuwornu, 2021; Ojo and Baiyegunhi, 2020; Thinda et al., 2020) have analysed factors influencing farmers' perception of climate change in general and their adaptation strategies. However, studies on how farmers perceived the impact of drought and factors influencing the perceived impact of drought is very limited. The second gap in literature is that studies on factors that affect farmers' choice of DRM are also few. The study therefore makes three essential contributions to literature on drought management in particular, and climate change in general. First, a principal component analysis was used to generate three key perceived impact: economic, environmental and social with 11 questions based on five-point Likert scale. Second, the study extends beyond considering how farmers perceived the consequences of drought to identify the determinants of perceived impact of drought through the application of seemingly unrelated regression (SUR) where economic, environmental and social dimensions of the perceived impact were used as the dependent variables. Finally, the study examines factors that influence the number of DRM strategies employed (intensity) to mitigate the risk and the negative outcomes of drought. In this case, the intensity of DRM was treated as dependent variable and fitted into

Count data model, precisely Poisson and negative binomial regression models. As the frequency of drought increases across the globe, particularly in the Free State province of South Africa, understanding how farmers perceived the negative consequences of drought and the factors influencing these perceptions, as well as the measures taken to mitigate the risk and the outcomes may be critical to design and implement technological and institutional policy options.

2. Methodology

2.1 Analytical frameworks

This study followed economic theory in order to achieve its objectives. First, PCA was used to generate indices of farmers' perception of the impact of drought on their livelihoods on the basis of a series of questions. Second, a seemingly unrelated regression (SUR) analysis was used to identify factors that affect farmers' perceptions of the impact of drought. Finally, count data modelling was used to examine the determinants of the intensity of the DRM strategies (intensity is defined as the number of drought-risk management) adopted by farmers to deal with the outcome of the drought. The following sections discuss the analytical techniques referred to above.

2.1.1 Principal component analysis

Multivariate analysis, particularly PCA, is one of the most commonly used approaches to identify the best possible combinations of a number of factors or variables that are thought to influence the outcome. The PCA technique reduces the dimensionality of the data sets while minimizing the loss of information. In this study, PCA was used to reduce the dimensionality of measuring the perceived impact of drought on farmers. The PCA creates uncorrelated indices where each index is a linear weighted combination of the initial element of the perceived impact (Thomas et al., 2011). The elements are ordered in the order of the first part (PC1) which describes all variables in the original data as the greatest possible variation (Filmer & Pritchett, 2001). Following Wale et al. (2021), PCA for this study was expressed as follows.

Consider that the following matrix denote the relationship between farmers' perceived impact of drought and a set of explanatory variables:

$$\begin{bmatrix} D_1 \\ \cdot \\ \cdot \\ D_n \end{bmatrix} = \begin{bmatrix} \beta_{01} \\ \cdot \\ \cdot \\ \beta_{0n} \end{bmatrix} + \begin{bmatrix} \beta_{1j} \\ \cdot \\ \cdot \\ \beta_{nj} \end{bmatrix} x_j + \begin{bmatrix} \varepsilon_1 \\ \cdot \\ \cdot \\ \varepsilon_n \end{bmatrix} \tag{1}$$

where $D_1 .....D_n$ are set of n dependent variables measuring perceived impact of drought, which can be expressed as a function of a set of independent variables (x_i) with parameter estimates ($\beta_{1j} .....\beta_{nj}$), intercepts ($\beta_{01} ......\beta_{0n}$) and error terms ($\varepsilon_1 ....\varepsilon_n$). The coefficient of the above equation could be estimated through linear structural equations based on the assumption that the dependent variable $D_1 ....D_n$ has a latent variables of the original observable dependent variables. We can apply PCA to the left-side of equation (1) to get equation (2) as follows:

$$\begin{bmatrix} D_1 \\ \cdot \\ \cdot \\ D_n \end{bmatrix} \cong \begin{bmatrix} P_1 \\ \cdot \\ \cdot \\ P_k \end{bmatrix} = \begin{bmatrix} \beta_{01} \\ \cdot \\ \cdot \\ \beta_{0k} \end{bmatrix} + \begin{bmatrix} \beta_{1j} \\ \cdot \\ \cdot \\ \beta_{kj} \end{bmatrix} x_j + \begin{bmatrix} \varepsilon_1 \\ \cdot \\ \cdot \\ \varepsilon_k \end{bmatrix}, \tag{2}$$

where $P_1 ...P_k$ denote principal components that have eigenvalues greater than one and $k < n$. k can be equal to one, where only one factor is retained or greater than one where more than one factors are retained as in the case of this study (see Table 3).

2.1.2 Seemingly Unrelated Regression analysis

Seemingly unrelated regression analysis was applied to the three dimensions (*D1, D2 and D3*) or components obtained from the PCA analysis. This is to acknowledge that the principal motive here is about how farmers perceived impact of drought on their livelihoods. The SUR enables us to identified the determinant of perceived impact of droughts from the three key perspectives: economic, environmental and social. SUR is a system of equations that are correlated across equations for an individual but uncorrelated across equations. Estimating the three equations (D1, D2 and D3) through SUR produces consistent and efficient parameter estimates as opposed to estimating each equation separately using ordinary least square technique. This is because SUR ignores the possibility of the residuals of the equations been correlated(Cameron and Trivedi, 2010).

The perceived impact of drought equations with three dependent variables can be estimated through SUR as follows:

$$\begin{aligned} d_1 &= \alpha_1 X_1 + \varepsilon_1, \\ d_2 &= \alpha_2 X_2 + \varepsilon_2, \\ &. \\ dm &= \alpha_m X_m + \varepsilon_m \end{aligned} \quad (3)$$

These equations are described as seemingly unrelated regression model and can expressed as;

$$d_i = \alpha_i X_i + \varepsilon_i, \qquad i = 1, \ldots\ldots d \quad (4)$$

The SUR model is based on the assumption that the residuals have zero mean or the X_i are strictly exogenous, homoscedastic and uncorrelated across observations. However, the equations within the system is correlated.

2.1.3 Intensity of drought-risk management strategies - Count data modelling

The number of strategies used by individual farmers described the dependent variable in order to identify factors that influence the intensity of the drought-risk management strategies. Cameron and Trivedi (1990) argued that the number of strategies adopted was a measure of intensity or diversity. Following Cameron and Trivedi (1990) and discussed in a number of studies such as Nkegbe and Shankar (2014), Mahama et al. (2020), Israel et al. (2020), the number of drought-risk management strategies used by farmers could be modelled by count data modelling. This is because the number of drought-risk management strategies used is counted in its natural form. The count data are non-normal and therefore cannot be estimated by the ordinary least square (OLS) estimator (Maddala and Flores-Lagunes, 2001). Standard regression models commonly used for count data analysis are Poisson regression and Negative binomial. The Poisson regression has the basic assumption of equidispersion (equality of variance and mean) while the negative binomial is responsible for over-dispersion (variance greater than mean). In a situation where the variance is less than the mean (under-dispersion) the Generalized Poisson regression analysis may be used. Zero-inflated Poisson and zero-inflated negative binomial are other types of count data models used to account for frequent zeros in the data (i.e. where zeros are more than expected.

Preliminary analysis of the sample data indicates that there are no excess zeros and that there is equidispersion. Thus, the Poisson regression model is well suited to the data set and is therefore used for analysis. Following Greene (2008), Poisson regression has a density function expressed as;

$$\Pr(H = h) = \frac{\lambda^{-\delta(h)} \delta_i (h)^H}{\Phi(1 + H)} \tag{5}$$

Where; $\delta_i = Exp(\Omega + L'\psi)$ and $H_i = 0,1,...i$ is the number of drought-risk management practices employed, and L is a set of predictors. Ω and ψ are the parameter estimates. Greene (2008) observed that the number of drought-risk management strategies used, δ is given as:

$$E(H_i = h_i) = \text{var}\{H_i \mid h_i\} = \delta_i = Exp(\Omega + L'\psi) \quad \text{for } i = 1,2,....n \tag{6}$$

2.2 The study area, sampling and data collection techniques

The survey was conducted in Thaba Nchu, Mangaung District of the Free State Province of South Africa. The district of Mangaung is centrally located in the province of Free State and covers a total land area of approximately 9887 km2 and a population of approximately 747,431 people (Statistics South Africa [Stats SA] 2011). The district is considered to be one of the most diverse economies and the largest contributor to GDP in the province of Free State (Mangaung Metropolitan Municipality Draft Integrated Development Plan 2017). Thaba Nchu is located 67 km east of Bloemfontein and has a more scattered pattern of development, with 37 villages surrounding the city centre. Agriculture and its related activities are the main source of livelihood. Residents are mainly smallholder farmers who cultivate maize, sunflower, wheat, potatoes, soybean and sorghum. Livestock breeding, mainly cattle and poultry, is also a major agricultural activity in the Thaba Nchu area. Figure 1 shows the map of the Manguang district of Thaba Nchu.

Figure 1: A map of Mangaung district showing Thaba Nchu Municipality, Free State Province, South Africa.

A multi-stage survey method was used and the Free State Province was predefined due to the prevalence of drought in recent years. The first stage of the survey was the random selection of Thaba Nchu from the many agricultural municipalities in the province of Free State. Thaba Nchu was then stratified into three strata: central, northern and southern, where appropriate sampling was applied to selected communities from each stratum. This is because there are 12, 21 and 12 communities in central, southern and northern Thaba Nchu, respectively. As a result, we selected two communities each from Central and Northern Thaba Nchu, while four communities were selected from Southern Thaba Nchu. With a simple random sampling technique, 40 farming households from each community were selected, making a total of 320 targeted respondents. However, a response rate of 94% was achieved, bringing the total sample size used for this study to approximately 301 respondents. Data was collected through a face-to-face interview using a comprehensive and well-structured questionnaire.

3. Results and discussions

3.1 Use of drought-risk management practices

Over the years, agricultural households have engaged in a number of risk management practices to minimize the negative impact of extreme weather variability, such as drought and floods. The Drought Risk Management Strategies identified in the study area are shown in Table 1. The most important aspect may not be the management practices themselves, but the way they are used or the benefits they receive. This section examines the different risk management practices chosen by farmers in response to drought on the basis of their available resources and external assistance. Some of these management strategies are used by farmers to avoid higher incomes and consumption shortfalls, while others are designed by stakeholders to help farmers recover or manage the risk of the event. Table 2 shows that the drought management strategy most frequently used in the study area was NGO intervention, which was used by 50.30% of farmers, followed by rainwater harvesting and the use of reserves/residues by 27.72% and 25.68% of farmers, respectively. Some farmers also managed the situation by either mortgaging their farmland or selling assets such as livestock, clothing, etc. Moreover, 16.60% of farmers sought employment elsewhere to cope with the event of drought, and 25.25% of farmers depended on government intervention as a means of coping strategy. The dependency on the government support program to help farmers overcome drought shock confirms the report by Shoroma (2014), which found that farmers in the village of Setlagole depended on the government to assist them with the necessary relief mechanisms to reduce the impact of the drought.

Table 1: Drought-risk management practiced by smallholder farmers

Drought-risk management strategies	*Percentage of farmers applied*
NGO intervention in the community (safety net program)	50.3
Seek new sources of food	5.11
Seek for employment somewhere	16.6
Keep reserves/residues	25.68
Selling of assets (e.g., farmland and livestock)	18.25
Rainwater harvesting	27.72
Maintaining flexibility	3.00
Government assistance	25.25
Crop insurance compensation	20.86

Another drought-risk management tool that is considered to be very important, but with less attention, is crop insurance or weather insurance. As indicated in Table 1, some 21% of respondents benefited from insurance as a coping strategy during drought. The increasing frequency and severity of droughts require the promotion of crop insurance; as financial institutions may not lend to smallholder farmers if they suspect a higher risk of default due to drought. Crop insurance, such as weather-based insurance, may be an attractive approach to managing drought-risk, as it uses weather indices such as rainfall to determine farmers' pay-outs and is faster and less dubious. As a result, insurance against extreme weather conditions can be more attractive and convenient to manage the risk of drought, especially for low-income farmers in Sub-Saharan Africa. Smallholder farmers in Thaba Nchu do not maintain flexibility as 97% of respondents did not use any flexibility maintenance as a coping strategy. Maintaining flexibility is a management strategy that allows households to switch between activities such as adjustment of input use (e.g. drought-tolerant crop varieties) as needed. In addition, the second least-used coping strategy in Thaba Nchu was to seek new food sources (5.0%). Although most farmers have used multiple management practices, some are beneficial, while others have perpetual adverse effects on their poverty situations. The incidence of drought is causing loss of assets to cope with the impact, widening the net trap of poverty and extreme poverty. Poor households that sell their assets may not be able to recover and have been trapped in the vicious cycle of poverty. Tesso et al. (2012) noted that poor households who sold their assets to cope with drought stress are about 18% less likely to recover. Some other strategies adopted to manage the negative impact of drought (e.g. migration to other areas of employment) could have a negative impact on family relationships as well as on knowledge capital.

3.2 Summary of descriptive statistics of the independent variables in the model

Descriptive statistics on the socio-economic variables used in the models to achieve the study objective are shown in Table 2. The proportion of males in the sample was 0.4, indicating that the majority of female respondents were female (60%). The average age was 53 years, with a relatively long farming experience of around 19 years. However, our respondents have a relatively low level of education, with an average of 9 years of formal education. Larger house sizes can be beneficial to households if they serve as a source of agricultural labour. However, more household members are exerting pressure on household food consumption, shelter and other resources. The results showed that the average household size was approximately 4.

Table 2: Description of independent variables

Independent variables	Description	Mean	Std
Proportion of male	1 if male; 0 otherwise	0.45	0.49
Age	Age of respondent in year	53.4	15.33
Educational attainment	Number of years in formal education	8.63	3.6
Experience	Number of years in farming	19.18	13.68
Household size	Number of members in a household	3.77	1.96
Non-farm work	1 if respondent engages in non-farm job; 0 otherwise	0.6	0.32
Seasonal farming	1 if respondent undertakes seasonal farming; 0 otherwise	0.67	0.47
Membership of farmer associations	1 if respondent is member of farmer associations; 0 otherwise	0.45	0.44
Access to extension services	Number of contacts with extension agents	2.78	1.41
Access to climate change information	1 if respondent access climate change information; 0 otherwise	0.38	0.31
Drought frequency	Number of times households experience drought in the last five years	1.78	1.18

On average, about 67% of the sampled farmers are engaged in seasonal farming, such as irrigation, mixed-cropping, multi-cropping and livestock farming. Irrigation and mixing of livestock and crops is one of the best adaptation measures in dry soil conditions (Hassan and Nhemachena, 2008). Dissemination of information is key to managing any kind of risk, including drought. Sources of information, such as farmer groups and extension services, as well as access to climate change information (e.g. information on early warning systems) are therefore key to managing the risk of drought. Table 2 shows that some 45% are members of the farmer group, while 38% have access to climate change information. On average, respondents had twice access to extension services in the year under study and had less than once experience of drought in the last five years.

3.3 Perceived impact of drought on livelihoods

This section presents the descriptive statistics (mean and standard deviations) of the 11 questions answered by our respondents on the perceived impact of drought and the results of the PCA analysis of the impact of drought as perceived by the respondents.

3.3.1 Descriptive statistics of the perceived impact of drought

The impact of drought on human life and the environment as perceived by the respondents is shown in Table 3. The severity of the effects of each indicator was measured at a scale of 1–5, with 1 being not severe and 5 being very severe. On average, farmers perceived drought as causing severe reductions in farm incomes and threatening their food security status. Drought outcomes include outbreaks of disease and pests, lack of water for plants and livestock, resulting in reduced crop yields and livestock deaths. They did not find much trouble, however, in their inability to take food rather than malnutrition. With regard to wildlife migration and frequent wild fires, they believe that drought has an important role to play. The mean severity score for the drying of water resources exceeds 3, suggesting that drought is perceived to have some serious consequences for their water bodies.

Table 3. Indicators of farmers' perceived impact of drought

Impact indicators	*Mean score*	*Standard deviation*
Reduction in farm income	4.0697	1.0856
Threatening food security	3.5647	0.8286
Unable to take preferred meal	1.9867	1.0518
Causes malnutrition	2.4186	1.0789
Migration of wildlife	3.9402	1.305
Loss of vegetation	2.5947	1.3887
Frequent wild fires	4.2525	1.4362
Drying up of water resources	3.75415	1.3364
Unemployment	2.7707	1.5046
Population migration	3.2059	1.2695
Reduction of expenditure on social festivities	3.1129	1.2195

In addition, farmers feel that drought has a moderate impact on unemployment, population migration and reduced spending on social festivities such as wedding ceremonies, naming ceremonies, festivals and funerals.

3.3.2 Dimensions of the perceived impact of drought on livelihoods

The PCA of the perceived impact of drought on the livelihoods of agricultural households in the Free State Province of South Africa produces three key factors with a value of >1, which explains about 55% of the total variation in the data set out in Table 4. Although there is no rule of thumb in the selection of the percentage variation, it is more appropriate and acceptable to consider at least 50% of the variation that could be attributed to the solution in studies such as this where the cross-section data used is susceptible to random errors (Hair Jr et al., 2014). The sampling adequacy of 0.81, as measured by the Kaiser-Meyer-Oklin (KMO) and Bartlet sphericity test, which is significant at 1%, confirms the adequacy of the PCA data. Field (2009) and Wale et al. (2021) has shown that a high KMO level indicates a relatively compact correlation pattern between variables and demonstrate that the factor analysis is more appropriate for the analysis of the data. The Cronbach Alpha Multi-Item Index of 0.78 shows that the 11 indicators are a reliable measure of the perceived impact of drought on livelihoods. Tavakol and Dennick (2011) noted that the Cronbach Alpha of 0.78 is an indication of a high level of internal consistency. It is also worth noting that the analysis considered only variables with a load of at least 0.5 components.

Generally, the main components were defined by the most central loading factors. The first factor (D1) reflects the perceived economic impact of drought, with all variables (threatening food security, unable to take preferred meals and reducing household income) describing the economic impact with positive factor loads. The first dimension (D1) was referred to as the *"perceived economic impact"* due to the set of variables describing the component. The economic impacts usually in the agricultural sector are due to the dependence of the surface and groundwater suppliers on the sector. Drought is associated with insect infestations, plant diseases and wind erosion, leading to crop and livestock losses and, as a result, to a reduction in household farm income. In addition, many households continue to experience food insecurity and malnutrition during drought periods. Drought also causes an increase in staple food prices, which can lead to hunger, malnutrition and poverty during periods of drought. The second component or dimension (D1) consists of four environmental variables; hence referred to as the *"perceived environmental impact of drought"* reflects what was perceived by respondents as the impact of drought on biodiversity and ecosystems.

Table 4. Principal component analysis results of the perceived impact of drought

Variable	*Components*		
	D1	*D2*	*D3*
Economic impact			
Threatening food security	**0.8075**	0.0288	0.0576
Unable to take preferred meal	**0.6557**	-0.0373	0.3552
Causes malnutrition	**0.5985**	-0.2899	0.2789
Reduction in household income	**0.7708**	-0.0797	0.0324
Environmental impact			
Migration of wildlife	-0.2680	**0.5915**	-0.2814
Loss of vegetation	-0.0173	**0.8124**	0.0284
Frequent wild fires	-0.0080	**0.7925**	-0.1505
Drying of water resources	-0.0653	**0.8326**	-0.0862
Social impact			
Result in unemployment	0.1517	0.0895	**-0.6138**
Population migration	0.2309	-0.0469	**0.7477**
Reduces expenditure on social festivities	0.1684	-0.1445	**0.7787**
KMO measure of sampling adequacy	*0.811*		
Bartlett's Test of Sphericity	*1079.38****		
Cumulative % of variance	*35.33*	*46.54*	*55.54*

**** denotes significant at 1%*

The impact of drought on the environment may result in damage to the quality of the air and water, forest and range fires and wildlife habitats and damage to the quality of the landscape. Degrading the quality of the landscape, including increased soil erosion, may lead to more permanent loss of biological productivity (Wilhite and Vanyarkho, 2000). The third dimension (D3) of the perceived impact of drought has a positive impact on population migration and a reduction in expenditure on social events (e.g. naming ceremonies, festivals, marriage ceremonies, etc.) but has a negative impact on unemployment. It reflects the perceived impact of drought on people's social lives; therefore, it is referred to as the *"perceived social impact of drought."* The three dimensions of the PCA are the dependent variables of the SUR analysis and the results are explained in section 3.4 below.

3.4 Determinants of perceived impact of drought

In order to guide effective and efficient policy options for climate change in general, and drought in particular, it is important to understand the factors that influence farmers' perceived impact of drought in three perspectives: economic, environment and social. Table 5 present the coefficient estimates of the perceived economic, environmental and social impact of drought from SUR model. From the SUR model, we performed correlation analysis to test the hypothesis that the error components of the three perceived impact equations are not correlated via the use of Breush-Pagan test. The test suggests that the null hypothesis of independence of economic, environmental and social impact should be rejected at one percent level of significance. Thus, it is appropriate to fit the three perceived impact equations using the SUR model.

Table 5: SUR model of perceived economic, environmental and social impact of drought

	Economic		*Environmental*		*Social*	
Variables	*Coeff.*	*Std. error*	*Coeff.*	*Std. error*	*Coeff.*	*Std. error*
Gender	0.6287***	0.2143	0.4293**	0.2180	0.0165	0.1959
Age	0.0098	0.0103	-0.0369***	0.0106	-0.0163*	0.0095
Educational attainment	0.0362	0.0321	-0.0535	0.0327	-0.0462	0.0294
Household size	-0.0555***	0.0113	0.0524***	0.0115	0.0237*	0.0104
Farming experience	-0.8868**	0.3696	-0.9311**	0.3760	-0.4606	0.3378
Monthly income						
less than 2000	1.8516**	0.9555	-2.6126**	0.9721	-3.0408**	0.8733
2001 - 5000	1.7575*	0.9961	-2.1796**	1.0133	-2.9553**	0.9105
> 5000	1.5387	1.0140	-1.4405	1.0315	-3.1954**	0.9268
Non-farm income	0.0294	0.0717	-0.1153*	0.0783	0.0668	0.0656
Access to climate change inf.	0.0862***	0.0088	0.2684***	0.0898	-0.0802	0.0807
Drought frequency	-0.9280***	0.0894	0.1780*	0.0910	0.2663***	0.0818
FBO membership	0.1306	0.0865	-0.0199	0.0879	-0.0921	0.0791
Extension services	-0.0379	0.0769	-0.1153	0.0783	-0.0861	0.0703
Constant	-1.5957	1.2909	3.6499	1.3132	4.2492	1.1798
R-squared	*52.94*		*50.29*		*45.61*	
Breush-Pagan test of independence: Chi^2(3) = 134.94; Pr = 0.000						

****, ** and * denote significant at 1%, 5%, and 10%, respectively.*

The respondent's gender leads to a positive perception of the economic and environmental impact of drought, but has no significant impact on the perception of the social impact of drought by the respondents. As a result, males are more in agreement with the devastating economic and environmental impact of drought. The age of respondents has a negative relationship with how the environmental and social impact of drought is perceived.

This suggests that elderly people perceived less severe environmental and social impacts of drought. This is quite surprising, as we expect older and more experienced farmers to see a serious impact on environmental and social livelihoods from drought. Mamba (2016) noted that the age of farmers determined how they perceived the impact of climate change on their livelihoods. Similarly, a respondent with many household members perceived a higher negative impact of drought on their livelihoods. This could be due to the fact that households with many mouths to feed suffer the most during drought, which will exasperate their negative perception of the economic, environmental and social impact of drought.

Another important variable that significantly influences how farmers perceive the impact of drought on their livelihoods is the number of years in farming. Experienced farmers have indigenous knowledge and are capable of perceiving climate variability and change and its consequences on the environment and agricultural household income. In addition, the lower and middle income classes perceived a greater economic impact of drought. This is far-fetched as the group of people with lower and middle incomes easily suffers when food costs are higher, resulting in food insecurity, malnutrition and poverty.

Table 5 also shows that access to information on climate change and variability has a positive impact on their perception of the economic and environmental impact of drought. Access to climate information makes farmers aware of the impact on their livelihoods of climate change and employs measures to mitigate the negative results. Therefore, the more farmers access drought-related information, the more they perceive and plan. This suggests the need to make climate information easily accessible to farmers in order to improve planning for drought adaptation and to mitigate adverse effects on their lives and the environment. Other studies (Ehiakpor et al., 2016; Ojo and Baiyegunhi, 2020; Thinda et al., 2020) have shown, similar to this study, that access to information on climate change gives farmers a better understanding of the climate impact, leading to better planning and implementation of measures against the negative effects of climate change, particularly drought. Likewise, the frequency of droughts experienced by farmers leads to a greater perception of the effect of droughts on people's economic and social lives as well as on the environment. This is not surprising because not only have those farmers heard of drought, but had experienced drying up of rivers, heat waves, lower rainfall and longer dry seasons. Smallholder farmers who experience drought usually lose their crops and livestock and face lower levels of income, food insecurity, malnutrition and unemployment as a result. Drought causes a depletion in the saving account of farmers and a limited growth potential in the next season's calving rate, according to the Bureau for Food and Agricultural Policy (2015), which consequently have long-term adverse effects on households' economic and social resilience.

3.5 Determinants of intensity of drought-risk management strategies

Determinants of intensity of drought-risk management practices adopted by agricultural households in the study area are reported in Table 6. Two count data models were estimated: Poisson regression and Negative binomial regression models. Model diagnostic tests were performed to determine whether Poisson or negative binomials fit the data properly. The *LR* Chi^2 value for Poisson is relatively large (60.56) compared to the negative binomial (56.50), suggesting that the Poisson regression model fits the data appropriately. The *lnapha* parameter for the negative binomial regression model is small and not significant even at the 10% level of significance, suggesting that the null hypothesis of equidispersion for the Poisson regression model cannot be rejected. In addition, the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) estimates are important diagnostic tests to identify a better model for the regression analysis. The AIC and BIC tests revealed that the Poisson model had lower values than the negative binomial model; therefore, the Poisson model was a better option. Thus, all diagnostic tests indicate that the Poisson model fits the data significantly well and should therefore be the focus model.

From Table 6, two variables of household demographic characteristics: age and household size influence the intensity of drought-risk management practices. The age of the respondent responds negatively to the number of drought-risk management practices adopted, suggesting that elderly is less responsive to adopting a number of strategies to combat the negative impact of drought compared to young and energetic respondents. This could be attributed to the fact that the younger generation is more innovative, less risky, always looking for information and ready to improve agricultural productivity. Older farmers may not be aware of modern agricultural innovations and strategies to minimize the risks and adverse effects of drought. This is consistent with the study of Ali and Erenstein (2017). Household size is negatively correlated with the number of drought-risk management practices adopted by farmers. This could be because drought-risk measures such as crop insurance, maintaining flexibility (e.g., planting drought-tolerance crop varieties) are quite expensive and households with large financial burdens due to many dependents may not afford to purchase these coping strategies. Although large household sizes are mostly considered to be farm and non-farm labour supplies, as many studies have noted (Abid et al., 2015; Zereyesus et al., 2017), this may not be the case for households with members who are young (usually children) because such households will need high costs to meet their family needs. These households are usually unable to take ex ante measures (e.g., purchase of crop insurance, drought-tolerance varieties) and can only adopt ex post strategies (e.g., sale of assets, decrease in food consumption and borrowing from neighbours) to cope with the drought situation. However, farmers with long-standing experience in crop farming are most likely to take a number of measures to avoid or minimize the risk of drought.

Table 6. Results on the determinants of intensity of drought-risk management strategies

	Poisson regression		***Negative binomial***	
Explanatory variables	***Coeff.***	***Std.***	***Coeff.***	***Std.***
Gender	-0.0175	0.0563	-0.0175	0.0563
Age	-0.0045**	0.0010	-0.0045**	0.0019
Education	0.0011	0.0083	0.0011	0.0082
Experience	0.1331	0.0938	0.1331	0.0938
Household size	-0.0271*	0.0146	-0.0271**	0.0146
Non-farm work	-0.1446***	0.0482	-0.1446***	0.0482
Membership of farmer associations	-0.0372	0.0242	-0.0371	0.0242
Access to extension services	0.0495**	0.0249	0.0495**	0.0248
Access to climate change information	0.0093	0.0235	0.0093	0.0235
Drought frequency	-0.0068	0.0242	-0.0068	0.0242
Perceived economic impact (D1)	-0.0804***	0.0307	-0.0804**	0.0308
Perceived environmental impact (2)	-0.0223	0.0311	-0.0223	0.0313
Perceived social impact (D3)	0.1114***	0.0331	0.1113**	0.0331
Constant	1.8162	0.1892	1.8161	0.1892
lnalpha			16.2696	460.9285
LR test of alpha			0.000	0.5000
Pseudo R				
LR Chi-square	60.56		56.5	
Probability > Chi				
AIC	1369.43		1371.43	
BIC	1424.98		1430.69	
Number of observations			300	

****, **, and * denote significant at 1%, 5% and 10%, respectively.*

Engagement in non-farm agricultural economic activities tend to have a negative influence on the number of drought-risk management strategies farmers practiced. Thus, farmers who have other sources of income are less likely to adopt more of the listed drought management practices compared with farmers who depend on agricultural activities as their sole source of livelihood. Participation in non-farm work offers households alternative sources of income that allow them to avoid certain measures such as selling assets (e.g. farmland, livestock, etc.), reducing food consumption, among others. During drought, some household members (especially the husband) migrate to other areas to engage in non-agricultural economic activities to meet the family's needs. This reduces the number of 'hard' drought coping strategies employed. Access to extension also plays a vital role in the intensity of drought-risk management strategies, as indicated by a positive and significant coefficient. Extension services provide information through which farmers know what's going on in their environment. Providing farmers with information not only on farm management practices, but also on how to prepare themselves to face the risk of extreme weather conditions, such as drought, helps farmers psychologically cope with drought stress. Asfaw et al. (2018) noted that there is a positive and significant link between climate change coping strategies and farmers' access to extension services.

In addition, farmers who perceived severe economic and social impacts of drought tend to use more of the drought-risk management strategies to mitigate the negative outcomes. The direct economic impact of drought in the agricultural sector is usually the loss of crops and livestock, which causes negative supply shocks and destabilizes the structure of the agricultural market. Farmers who perceived severe outcome of such disruption used strategies such as rainwater harvesting as a source of drinking water for themselves and animals, as well as irrigating their crops. Some other farmers store food crops such as maize, rice, etc. as reserves and residues for their animals. In addition, farmers who perceived drought to have a very severe impact on their crops may purchase crop insurance, which will be compensated by insurance companies for a proportion of their crop losses. They may also register and receive disaster assistance from NGOs and the government. Drought may, however, create winners. This is because farmers who have perceived the higher impact of drought on food prices may take advantage of this by hauling their crop output to benefit from favourable prices. Consequently, the negative economic impact of drought is not entirely borne by farmers, part of which is passed on to consumers (Ching et al. 2011).

4. Conclusions and policy recommendations

Irregular and unforeseen variations in climate present difficult situations for the world, particularly those that depend on agricultural activities as their primary source of livelihood. Extreme weather conditions such as drought are one of the major contributors to food insecurity, malnutrition and poverty. The extent to which farmers have perceived the impact of drought on socio-economic life and the environment, as well as their management strategies, is crucial to policy implications. This study made small but significant contributions to the empirical literature on climate change in three ways: (1) analysed how farmers see the impact of drought on their livelihoods through PCA; (2) identified the determinants of perceived impact of drought using SUR; and (3) examined factors that influence the intensity of drought-risk management strategies used by farmers in the Thaba Nchu mun using count data modelling.

PCA results show that farmers understand how climate change, particularly drought, affects their lives and the environment, and that, on average, farmers feel that the impact of drought is serious. Gender, age, household size and farming experience are demographic factors that tend to influence their perception of the impact of drought. Access to information on climate change was also a significant factor in how farmers perceived the impact of drought. Knowledge is a significant precursor for people to form their perception, which is intended to help them adapt appropriately to situations. In the event of drought, farmers with prior information may be less vulnerable as they may have prepared themselves in advance. It is therefore important to strengthen improved early warning systems in local communities in order to reduce vulnerability. The dissemination of such climate information to provide prospects with lead times of two to six months prior to the start of the event will help farmers plan their adaptation and coping strategies.

The results further indicated that obtaining assistance from NGOs and communities and selling or mortgaging their farmland are common drought-risk management strategies used by farmers to cope with the negative outcome of the drought. Factors that have a significant effect on intensity of drought-risk management strategies include age, household size, non-farm work and extension services. The study therefore recommends that demand-driven extension services that address the needs of people at a particular point in time is critical to the lives of farmers. Climate risk management can be integrated into the provision of extension services, particularly in drought-prone areas such as the province of Free State. In this case, farmers are not only trained in agricultural technology, but also in the management of drought-risk. This makes farmers less vulnerable to climate shocks and serves as a strategy to combat food insecurity and long-term poverty. Encouraging farmers to engage in non-agricultural economic activities is also critical, as this can serve as insurance against events such as drought.

Declarations

Availability of data and materials

The datasets used to analyse this study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that there exists no competing interest.

Funding

The study did not receive direct funding for publication.

Authors' Contribution

All authors contributed to the different stages of the study. GDA conceptualized the idea, was involved in the analysis of the data, and wrote the draft manuscript. AOO supervised the study and provided comments on the manuscript. TOO was actively involved in the data analysis and interpretation. CCO collected the data. All authors read and approved the final manuscript.

Acknowledgement

The paper is based on research that was conducted as part of a research project, “farmers’ coping and adaptation strategies to drought and other water related risks in a changing climate (TTK160610170148)”, which was funded by the National Research Foundation (NRF) through the Thuthuka funding instrument (NRF rating track) grant. Financial and other assistance by the NRF are gratefully acknowledged. Financial assistance by the University of the Free State through the Central Research Fund (CRF) of the Faculty of Natural and Agricultural Sciences is also gratefully acknowledged.

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Figures

Figure 1

A map of Mangaung district showing Thaba Nchu Municipality, Free State Province, South Africa. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.