

Article

Smallholder Farmers' Adaptation to Drought: Identifying Effective Adaptive Strategies and Measures

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Abstract: One of the biggest challenges for South African food security is recurring drought. It is a major concern due to insufficient knowledge and the low levels of resources or livelihood assets available to farmers in vulnerable situations, thereby limiting coping and adaptation choices. The objective of this paper was to identify the current adaptation and coping measures used by smallholder farmers, with a particular emphasis on farmers' vulnerability to drought and the adaptive measures or strategies that are effective in the study area. In addition, we determined factors influencing their choice of adaptation strategies. In this way, the extent of farmers' vulnerability and how this affects the choice of coping or adaptation strategies during drought were determined. The multinomial probit model (MPM) was used to examine the factors that influence farmers' choice of coping/adaptation strategies in the study area. The results show that the respondents' human capital vulnerability to drought was very high compared to their economic and social vulnerability. Influences such as age, gender, and marital status contributed to their human capital vulnerability. The majority of the respondents implemented water-use restrictions as a coping strategy during drought periods. There were several reasons for this, such as the resources available, the effective coping strategy for that specific location/area, and the socio-economic status of the respondents. The inadequate contribution by the government to drought risk reduction, the age of the respondents, the monthly income of each household, and the inequality of decision-making powers between male and female respondents were also found to contribute greatly to choosing an effective adaptation strategy. This study contributes to the ongoing investigation of the adaptation strategies and coping measures used by farmers vulnerable to drought in arid and semi-arid areas in Africa. This is done by identifying effective adaptation and coping measures within the farmers' operational environment, unlike other studies that have only identified adaptation and coping strategies without examining their effectiveness in the given environment. Also, the inclusion of the human, social, economic, institutional, natural, and political forms of capital as determinants of the farmers' choice of adaptation and coping measures provides relevant insights for efficient and sustainable policy design.

Keywords: drought; effective adaptation; vulnerability; water scarcity

1. Introduction

Drought is one of the most disastrous climate-related threats in the world, and affects agriculture, the environment, infrastructure, and socioeconomic activities [1]. Drought is defined as an insufficiency of rainfall over an extended period of time, usually a period of a month or more,

resulting in a shortage of water and giving rise to adverse effects on vegetation, animals, and people [2,3]. Droughts are an endemic feature of the African landscape [4].

Agriculture is a major social and economic sector in the Southern African Development Community (SADC) region, contributing between 4% and 27% of the region's gross domestic product (GDP). The majority of the population in the region depend largely on agriculture for their primary source of livelihood, employment, and income [5]. Smallholder farming is the most widely used method of agricultural farming in Sub-Saharan Africa, with the majority of the rural poor depending on it for survival [6].

Drought is a recurrent phenomenon, occurring at different intensities in South Africa [7]. The year 2015 was officially declared the driest year in South Africa since 1904 [8]. Resource-poor farmers, whose productivity is highly threatened by frequent droughts, are affected the most. These droughts are due to the high inconsistency in inter-annual and intra-seasonal rainfall over most parts of South Africa [3,9]. In semiarid regions such as the Free State province of South Africa, drought is the climate hazard that has the most harmful effect on farmers [10]. The risks posed by drought are dependent on the interaction of drought with the vulnerability of both human and natural systems, as well as their ability to adapt [11].

An important part of the solution to the drought problem is to put people who are vulnerable at the centre of communication for adaptation. This requires treating the end users of information not merely as a target audience, but as partners in co-learning through processes and products that reflect their own contributions [12]. There are a number of success stories about adaptation among the most vulnerable, but they are mostly from developed countries and have been developed into projects [13]. It has not become imperative to accelerate the process of replication and dissemination of best practices. Drought adaptation and coping strategies need to be promulgated among vulnerable farmers, and this requires innovative approaches towards knowledge sharing.

During periods of drought and beyond, smallholder farmers often lose their livelihood and investment in agriculture. During drought periods, smallholder farmers cannot manage or cope without external assistance in terms of relief packages from governmental and non-governmental agencies [14]. Drought can lead to food shortages and social unrest, and can stall land redistribution. In many areas, drought has forced farmers to sell off some of their livestock to buy fodder for the remainder [15]. Insufficient knowledge and the low levels of resources or livelihood assets available to farmers during vulnerable situations such as drought and other climate hazards limit coping and adaptation choices. In addition, reducing vulnerability is a key feature of improving smallholder farmers' adaptive capacity and resilience to drought. However, the extent to which farmers' levels of vulnerability influence their choice of coping or adaptation strategies remains uncertain. Studies focus on the socio-economic aspects of global climatic variability, almost exclusively restricting their analyses to the impact of the environment on agricultural production [16].

Previous studies suggest that drought can affect different areas and people within the same area differently [17–20]. Tung et al. [18] revealed that there is an association between climate risk components, including hazard, exposure, and vulnerability. Eckstein et al. [19] confirmed that emerging economies are more vulnerable to climate risk compared to developed economies. Abeygunawardena et al. [20] are of the opinion that climatic changes progressively affect the poor and, as such, there is a need for adaptation strategies. The subsequent effects felt by households or individuals, as well as their coping strategies or mechanisms, could be influenced greatly by their previous status in terms of access to various capital or assets, such as wealth, information, financial aid, and loans [17,18]. The problem is that vulnerability is not accounted for, and smallholder farmers are the ones who are affected the most, being the most vulnerable during the occurrence of drought because they depend on agriculture for their livelihood [19–21]. Apata, Samuel, and Adeola [21] found that perception and adaptation studies help to better understand communities' perceptions of climate change and their existing adaptation strategies. Most of the existing studies have focused only on identifying farmers' adaptation strategies without trying to discover which of the identified strategies are effective in coping with drought [12,13,18,21]. Therefore, it is imperative to identify

adaptation strategies that are effective and efficient in mitigating or adapting to the impact of drought.

The objective of this paper was to identify the current adaptation and coping measures used by smallholder farmers in Thaba 'Nchu, with particular emphasis on farmers' vulnerability to drought, as well as the adaptive measures or strategies that are effective in the study area. Secondly, we determined factors influencing their choice of adaptation strategies. In this way, the extent of farmers' vulnerability and how this affects their choice of coping or adaptation strategies during drought was determined.

The study contributes to existing knowledge in the following ways: First, the study contributes to the pursuit of effective and sustainable adaptation strategies and coping measures in relation to drought in arid and semi-arid areas in Africa. This study does not focus only on general adaptation and coping measures within the farmer's operational environment, but rather places emphasis on adaptation strategies and coping measures that are effective in the farmer's geographical location. Second, we contribute to existing knowledge on traditional socio-economic factors that influence farmers' adaptation strategies and coping measures by including vulnerability capital such as human, social, economic, institutional, natural, and political capitals.

2. Relevant Literature and Gaps

Studies suggest that farmers' perceptions of the adoption of soil fertility management practices are strongly linked to their experiences and knowledge of the practices [22,23]. For instance, Meijer et al. [23] argue that the knowledge farmers have about a new practice is closely related to their perceptions of such a practice, which together frame their attitudes towards whether or not to adopt the practice. Ervin and Ervin [24] argue that farmers' personal characteristics, such as age and education, also play a critical role in framing their perceptions of adoption [25].

Risk influences farmers' attitudes to and perceptions of adoption behaviour [26]. Risk-averse farmers easily adopt new conservation practices that they perceive to reduce risk [27] and that are in line with their economic motivations and goals [28]. In addition, personal farmer characteristics, such as wealth (livestock, land, cash), past farming experience, as well as age, greatly influence their risk attitudes and perceptions [26].

Farmers' education levels are used to determine whether education has an influence on how they perceive the amount of rainfall at the start of a farming season. According to Mamba [29], education level influences perception. Farmers who correctly perceive the amount of rainfall expected at the beginning of the farming season are those who either have training in certain skills, or have a tertiary level or at least secondary level of education. However, the majority of farmers without any form of education wrongly perceive the amount of rainfall as low or average when, in fact, it is actually plenty or above average [29]. Access to extension services and weather information affects how farmers perceive climate variables. Those farmers with access to extension services and weather data tend to perceive the amount of rainfall at the start of a farming season correctly.

Legesse, Ayele, and Bewket [30] conducted a study in the Doba district of Ethiopia and found that the frequency of extension contact and training were the determining factors influencing perception and adaptation strategies. This is similar to a study by Kamruzzaman [31], conducted in the Sylhet Hilly Region in Bangladesh, who also observed that access to weather information influences farmers' perceptions. This means that access to extension services needs to be improved as a step towards improving farmers' perceptions of climate change and variability [29].

Bryan et al. [32] found that gender is another important factor that influences how farmers perceive climate change and variability. This is not surprising for Swaziland, as women are more active in farming than men. It therefore is expected that, on the basis of their level of engagement in farming activities, which gives them experience, women are well positioned to perceive correctly the amount of rainfall at the beginning of each farming season, which is what they do every year [29]. According to Adesina and Zinnah [33], farmers' perceptions of technology-specific traits have been a major factor conditioning adoption behaviour. This strongly confirms the hypotheses that farmers' perceptions of the attributes of agricultural technologies determine their adoption choices.

Coping strategies can be classified as pre-drought and post-drought strategies. The classification depends on whether these strategies can help reduce the risk of or alleviate the impact on the shortfall in the production in a certain period [34]. Several drought coping mechanisms are used around the world. Hazelton, Pearson, and Kariuki [34], Panley [35], Tideman and Khatana [36], and Wilhite [37] found that the use of drought-coping strategies is a major accomplishment that enables or provides the community with some capacity to cope. According to Hazelton, Pearson, and Kariuki [34], drought-coping strategies are made up of a number of drought mitigation measures. Drought mitigation measures comprise ecological, social, environmental, and technological measures that aim to alleviate drought impacts and equalise losses [38]. Therefore, adaptation to climate change includes all adjustments in behaviour or economic structure that reduce the vulnerability of society to changes in the climate system [39].

In South Africa, Olaleye [17] illustrated that farmers in the Free State province adopt coping mechanisms during periods of drought. These farmers' coping mechanisms include gardening, selling vegetables, casual labour, selling livestock and livestock products such as milk, and limited use of credit. Unlike in other countries of the world, the sale of personal effects (such as jewellery or watches), household effects (such as furniture), or agricultural equipment to raise cash during drought emergencies occurs only in rare cases [17]. The three most important adjustment mechanisms are the sale of livestock, the use of financial assets, and additional employment [17].

Ngaka [40] found that farmers in the Eastern Cape and Free State provinces of South Africa are willing to pay for livestock feed in order to maintain a nucleus herd of cattle. The majority of farmers indicate that they sell their livestock as a measure to cope with devastating drought conditions. The sale of livestock tends to be a drastic measure for emerging small- and medium-scale farmers to alleviate the impact of a drought disaster. Other coping strategies include movement of livestock to better grazing camps, purchase of remedies—particularly vitamin A supplements—fetching water for livestock, and weaning calves earlier than usual [40].

According to Benhin [41], farmers across South Africa have identified a number of adaptation options to address the changes they perceive in climatic conditions. The main adjustments in farming activities include adjusting farming operations, such as changes in planting dates of some crops, planting crops with a shorter growing period such as cabbage, and planting short-season maize. Others include the increased use of crop rotation and the early harvesting of some crops. Not all the adaptation strategies are effective in all geographical areas [34–37]. However, none of the existing studies examined effective adaptation strategies in the Free State province of South Africa, particularly in Thaba 'Nchu.

3. Methodology

3.1. The Study Area

South Africa is a semi-arid to arid country with a highly variable climate and highly constrained freshwater resources. The limited water resources are affected by weather extremes imposed by climate variability and change. Drought, which has a devastating impact on the country, is a recurrent characteristic feature of the country's highly variable climate and weather extremes. It is one of the most disturbing natural disasters worldwide, of which the socio-economic impact tends to be severe in regions with an annual rainfall of less than 500 mm. Figure 1 shows that South Africa's rainfall data for the period of January to December 2015 was 405 mm, which is below the 608 mm calculated as average for the period 1904 to 2015.

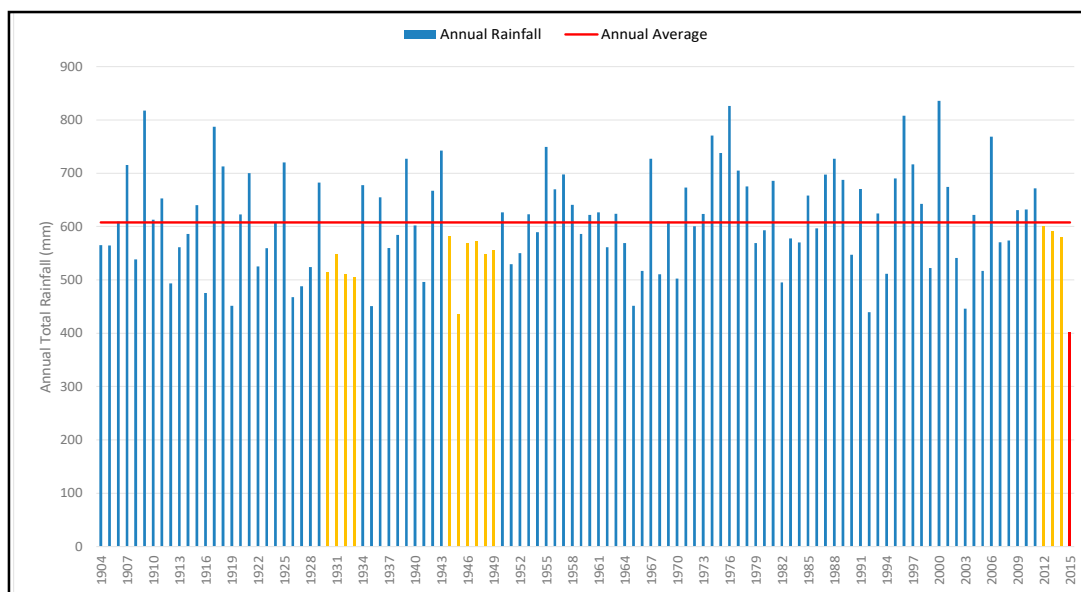


Figure 1. South Africa's annual total rainfall from 1904 to 2015 [8].

Throughout the twentieth century, droughts occurred across South Africa with great regularity [42]. According to the South African Weather Service, any amount of rain that is less than 75% of normal annual rainfall constitutes a meteorological drought. In South Africa, drought days have been experienced over the past 15 years, during which the key part of the nation has received below-normal rain [43]. The main drought years have been 1991/1992, 1997/1998, 2001/2002, and, more recently, 2015/2016 [40].

Thaba 'Nchu is located 67 km east of Bloemfontein and has a scattered development pattern, with 37 villages surrounding the urban centre, some as far as 35 km from the centre, and others 12 km further to the east of Botshabelo, which used to be part of the Bophuthatswana "Bantustan". The population is made up largely of Tswana and Sotho people. The town was settled in the 1830s and officially established in 1873. The town grew larger following the 1913 Natives Land Act, which set Thaba 'Nchu aside as a homeland for the Tswana people. As a result of its settlement history, the region has a large area of rural settlements on former trust lands.

The area is characterised by vast stretches of communal grazing areas that surround the urban centre. Many residents still keep cattle within the urban area, and this creates a problem for residents. The majority of new urban developments have taken place towards the west, along Station Road, while the central business district has developed to the east of these extensions. Again, this leads to some urban communities in the urban core being as far as eight kilometres from any economic opportunities. Thaba 'Nchu has always been a major service centre for the Eastern Free State, with many government departments establishing regional offices in this area. However, many of these offices and amenities have recently closed down, thus leaving the town crippled in terms of economic investment [44].

The province experiences annual rainfall of between 600 mm and 750 mm in the east; this declines slowly to 250 mm in the south-western parts of the province. The winters are sometimes very cold, with heavy frost over most of the province. The average winter temperatures range between 12.5 °C and 15.0 °C in the eastern parts of the province, and increase to an average range of 17.5 °C to 20 °C in the west during the summer [45]. January is the warmest month of the year, with an average temperature of 21.5 °C in Thaba 'Nchu, while June is the coldest month, with 6.9 °C on average. The average annual rainfall of Thaba 'Nchu is 629 mm, while the average annual temperature is 15.2 °C. This is higher than that of other districts, which have an average annual temperature of 14.8 °C [46]. The main farming activities in the study area include production of grains

and cereals, such as maize, wheat, and sorghum. Groundnuts are also grown in the study area, along with vegetables. Livestock production is also very popular. Figure 2 shows the map of the study area.



Figure 2. Location of the study area. Source: Mangaung Metropolitan Municipality.

3.2. Sampling

The survey employed the multistage sampling approach. In the first stage, the Free State province was sampled because it is one of the major grain-producing areas in South Africa. The province was also selected because of the prevalence of drought over the past years. In the second stage, Thaba 'Nchu was randomly selected from a list of farming municipalities in the Free State province. A complete list of all villages in Thaba 'Nchu was obtained from the Department of Agriculture. Thaba 'Nchu is divided into three areas—Central, Northern, and Southern Thaba 'Nchu. Central Thaba 'Nchu contains 12 villages, while Northern and Southern Thaba 'Nchu consist of 21 and 12 villages, respectively. Given the different number of villages in the three areas, we used proportionate random sampling to select villages for the survey. Two villages each were selected from Central and Southern Thaba 'Nchu, and four villages were selected from Northern Thaba 'Nchu. Forty farmers were targeted from each of the selected villages using simple random sampling. A total of 301 responses were obtained out of the 320 targeted. The response rate for the survey was 94%.

3.3. Data Collection

The study used cross-sectional data collected from 301 farmers. A questionnaire was developed following the guidelines of Cox [47]. The comprehensive and structured questionnaire was written in English and consisted of six sections. Sections A and B included questions relating to demographic information. Section C covered the farmers' perceptions of drought, while section D investigated drought vulnerability, section E covered adaptation and coping mechanisms, and section F covered

the vulnerability indicators. The questionnaire was pilot-tested to check its suitability. Data were collected through face-to-face interviews with the farmers. The questionnaire included a combination of open-ended and closed-ended questions. Also included were Likert-type scale questions in relation to which the farmers had to rate the importance of a specific question, and ranking questions in terms of which farmers had to rank a set of options by numbering them. The questionnaire was confidential and anonymous. The questionnaire was pretested with 10 respondents in the study area before the actual data collection. Permission to collect data was granted by the extension officers of the Thaba 'Nchu Department of Agriculture.

3.4. Vulnerability Indices

Vulnerability indices were calculated using the approach of Cutter, Boruff, and Shirley [48]. The calculation of the vulnerability capital indicators comprises several steps, including indicator selection, normalisation, weighting, and aggregation into a final index [49]. The indicator weighting was based on principal component analysis (PCA). The weights from the PCA were subjected to expert judgement. The indicator weighting was done to explore any correlation amongst the indicators to identify overlapping information and to choose an appropriate weighting and aggregation approach for the final index calculation [48,50]. The total vulnerability was calculated by summing the individual capital indexes.

For a given vulnerability capital, we specified the equation as

$$VCP_c = \sum_{i=1}^C w_i \times indicators_i \quad (1)$$

where VCP is the individual vulnerability capital index for C (i.e., human, social, economic, institutional, natural, and political capitals); and w_i is the weight for the individual indicators for a given capital. The weights were generated from the PCA. The factors defining a given capital are denoted by $indicators_i$. The total vulnerability is the sum of the human, social, economic, institutional, natural, and political capitals. Details of the indicators or items used in the estimations of the indexes are available upon request from the authors.

3.5. Empirical Model

The study employed a multinomial probit model (MNP), as the dependent variable in this study had more than two options. The advantage of using an MNP model is its computational simplicity in calculating the choice probabilities, which are expressible in analytical form [51]. This model provides a convenient closed form for underlying choice probabilities with no need for multivariate integration, making it simple to compute choice situations characterised by many alternatives. In addition, the computational burden of the MNP specification is made easier by its likelihood function, which is globally concave [50]. The MNP model allows household characteristics to have different effects on the relative probabilities of any two choices being made. With the adoption of a specific choice, the MNP model specifies the following relationship between the probability of choosing A_i and the set of explanatory variables X [52,53] as

$$\Pr(A_i = j) = \frac{\exp \beta_j x_j}{1 + \sum_{k=1}^J \exp \beta_k x_i}, \quad (2)$$

where β_j represents the set of regression coefficients associated with the outcome of the independent variable X . Equation (2) can be normalised to remove indeterminacy in the model by assuming that $\beta_j = 0$, and the probabilities can be estimated as

$$\Pr(A_i = j / x_i) = \frac{\exp \beta_j x_i}{1 + \sum_{k=1}^J \exp \beta_k x_i}, j = 0, 1 \dots J, \beta_0 = 0. \quad (3)$$

Estimating Equation (3) yields a J log-odds ratio,

$$\ln \left(\frac{P_{ij}}{P_{ik}} \right) = x_j^i (\beta_j - \beta_k) = x_j^i \beta_k, \text{ if } K = 0. \quad (4)$$

The choice of drought adaptation strategies is therefore the log-odds in relation to the drought-related strategies, which serve as the base alternative. According to Greene [53], the coefficients of the multinomial logit are difficult to interpret, and associating β_j with the j th outcome is tempting and misleading. The marginal effects are usually derived to explain the effects of independent variables in terms of probabilities, as presented in Equation (5):

$$\frac{\partial p_j}{\partial x_i} = P_j \left[\beta_j - \sum_{k=0}^J P_k \beta_j \right] = P_j (\beta_j - B). \quad (5)$$

The marginal effects measure the expected change in the likelihood of the choice of a particular climate-related strategy with respect to a unit change in an exogenous variable. The empirical model was specified as

$$\begin{aligned} Y_{ij} = & \beta_0 + \beta_1 Age + \beta_2 Educ + \beta_3 HHsize + \beta_4 FExpr + \beta_5 Ftrain \\ & + \beta_6 Gender + \beta_7 Mstat + \beta_8 Offfar + \beta_9 Inco + \beta_{10} Drofreq + \beta_{11} HCI \\ & + \beta_{12} SCI + \beta_{13} ECI + \beta_{14} ICI + \beta_{15} NCI + \beta_{16} PCI + \varepsilon_i \end{aligned} \quad (6)$$

Table 1 shows the explanatory variables hypothesised to influence the farmers' choice of effective adaptation strategies. It also shows the variables used in the model and the measurement index, and the expected sign or a priori expectation in relation to any of the adaptation strategies is included in the last column.

Table 1. Definition of independent variables for multinomial logit analysis.

Variable	Description	Expected Sign
Age of household head (Age)	Age in years	\pm
Education level (Educ)	Educational level of household head; 0 = No formal education, 1 = Primary education, 2 = Secondary education, 3 = University degree	+
Household size (HHsize)	The number of household dependants	\pm
Farming experience (FExpr)	Farming experience in number of years	\pm
Farming training (Ftrain)	Farming training: 1 = Yes, 0 = No	+
Gender	Gender of household head: 1 = Male, 0 = Female	+
Drought frequency	Drought frequency (continuous variable)	+
Marital status of household head (Mstat)	1 if Married, 0 otherwise	+
Off-farm business (Offfar)	If respondent has off-farm business: 0 = Yes, 1 = No	+
Household income (Inco)	Average household income: 0 = Less than R2001; 1 = R2001–R5000; 2 = R5001–R10,000; 3 = R10,001–R20,000	+

Drought experience (Droexp)	Experienced drought: 1 = Yes; 0 = No	–
Human capital index (HCI)	Continuous variable calculated from age, education, gender, skills, and experience	±
Social capital index (SCI)	Continuous variable calculated from family support, formal and informal groups, networks, and connections	±
Economic capital index (ECI)	Continuous variable calculated from access to information, insurance, marriage, salary/wages/income, alternative sources of income, and unemployment	±
Institutional capital index (ICI)	Continuous variable calculated from farmers' associations, environmental health, Non-Governmental Organizations, and extension services	±
Natural capital index (NCI)	Continuous variable calculated from soil erodibility, ground water, and irrigation land	±
Political capital index (PCI)	Continuous variable calculated from political stability, policies, governance, government support, and government drought scheme	±

Source: author's compilation.

4. Results and Discussion

4.1. Characteristics and Background of Respondents

Table 2 presents the descriptive characteristics of the respondents. The respondents' mean age was 53 years, with about 19 years of farming experience. This means that, on average, smallholder farmers in Thaba 'Nchu were relatively middle-aged, having many years of farm experience and relatively small household sizes (average of four members per household). The results are similar to those of Nyam [45], who found that smallholder farmers in Thaba 'Nchu were on average 54 years old and had an average of four people in their household. The survey results show that 5% of the household heads in Thaba 'Nchu had no formal education, 37.9% had completed primary education, 42.9% had obtained secondary education, while 13.6% had a college certificate or diploma, and only 0.6% had attained university education (degree and doctorate). This is consistent with Stats SA [54] data, which show that 4.3% of farmers have no formal schooling. Less than half (44.9%) of the respondents were married, and the remaining were either single, widowed, divorced, or separated.

Table 2. Descriptive statistics of respondents ($n = 301$).

Variables		Mean	Standard Deviation
Age (Years)		53.40	15.330
Farming experience (years)		19.18	13.689
Household size		3.77	1.996
Gender	Male	0.55	0.14
	Female	0.45	0.20
Education	No formal education	0.05	0.01
	Primary education	0.38	0.13
	Secondary education	0.43	0.15
	University education	0.14	0.02
Marital status	Married	0.45	0.13
	Other (single, divorced, widowed)	0.55	0.17
Monthly income	Less than R2000	0.82	0.21
	R2001 to R5000	0.13	0.07
	R5001 to R10,000	0.04	0.02
	R10,001 to R20,000	0.01	0.00
Access to climate information	Yes	0.41	0.12
	No	0.59	0.15

Most respondents (82%) earned less than R2000 a month, while only 13% earned between R2001 and R5000. Few households earned more than R5000 to R20,000 a month. Stats SA [55] data show the annual income of household heads in Thaba 'Nchu to be no income (26.6%), earning between R1 and R4800 (3.8%), earning between R4801 and R38,400 (51.3%), earning between R38,401 and R307,200 (15.0%), and earning more than R307,201 (1.9%) [55]. The respondents were asked if they received early warning system information and climatic advisories about drought. We found that 41% of the respondents had access to climate information. Thus, more households had no access to climate information. This is similar to the findings of Mandleni and Anim [56], who found that most livestock farmers who were unsure of climate change were not receiving climate information. Nevertheless, climate services exist, such as weather forecasts on rainfall, temperature, and humidity, as well as early warning weather information. As indicated in the results, however, access to the available information is insufficient and should be improved. Extension services available to farmers include crop production and protection advisory services, animal husbandry practices and disease prevention, construction of irrigation facilities, and water usage and saving technologies. An improvement in extension-to-farmer ratio is necessary to enhance accessibility.

4.2. Respondents' Vulnerability to Drought in the Study Area

Figure 3 presents the respondents' vulnerability indices. It can be seen that human capital had the highest index of 3.13, followed by natural capital, having an index of 2.94, and social capital, having an index of 2.82. Political and institutional capitals had indices of 2.73 and 2.63, respectively. The capital with the lowest vulnerability index was financial/economic capital, having an index of 2.58. Therefore, the high capital index means that the respondents were more vulnerable in terms of human capital, while the lowest capital index means the respondents were less vulnerable in terms of financial/economic capital.

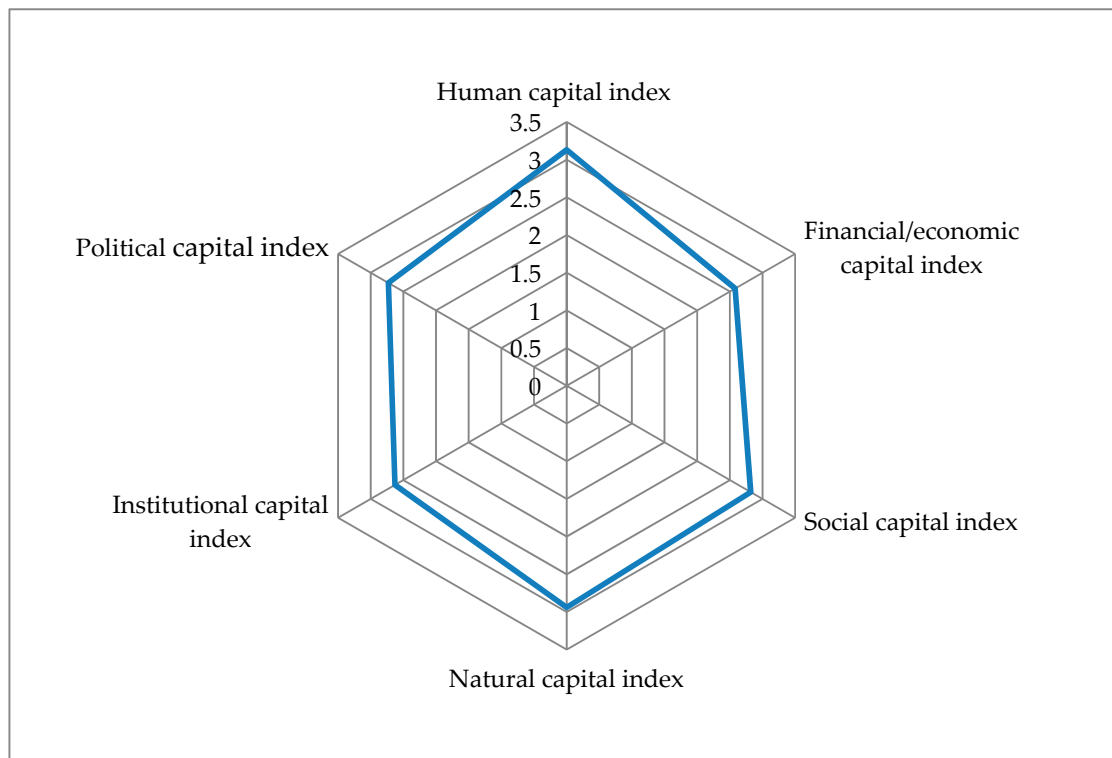


Figure 3. Vulnerability spider diagram of respondents' livelihood assets/capitals. Source: authors' calculation.

Human capital includes indicators such as age, education, gender, experience, and skills. The human capital index was most vulnerable in terms of livelihood strategies. Adu et al. [57] found that the socio-economic profile shows greater vulnerability compared to the other forms of capital.

4.3. Coping and Adaptation Strategies Used by Respondents in Thaba 'Nchu

Coping capacity is the ability of people, organisations, and systems, using skills and resources, to face and manage adverse conditions and disasters [58]. Table 3 presents the respondents' coping strategies and Figure 3 presents their adaptation measures used during the 2015/2016 drought.

Table 3. Respondents' coping strategies used during the 2015/2016 drought.

Coping Strategies	Yes		No	
	%	Frequency	%	Frequency
NGO intervention in the community	10.6	32	89.4	269
Seeking new sources of food	5.0	15	95.0	286
Seeking employment elsewhere	16.6	50	83.4	251
Keeping reserves	8.6	26	91.4	275
Rainwater harvesting	27.2	82	72.8	219
Maintaining flexibility	1.0	3	99.0	298
Getting assistance from the government	25.2	76	74.8	225

Source: field survey.

Figure 4 shows the respondents' ratings of different adaptation strategies on a scale of 100 in terms of their effectiveness in the study area. These strategies were rated independently. The results show that 74% found technical measures to be effective. Water efficiency and awareness raising campaigns were rated at 85% and 87%, respectively. Improving forecasting and policy were rated at 83% and 85%, respectively. Water-use restriction was rated lower, at 58%.

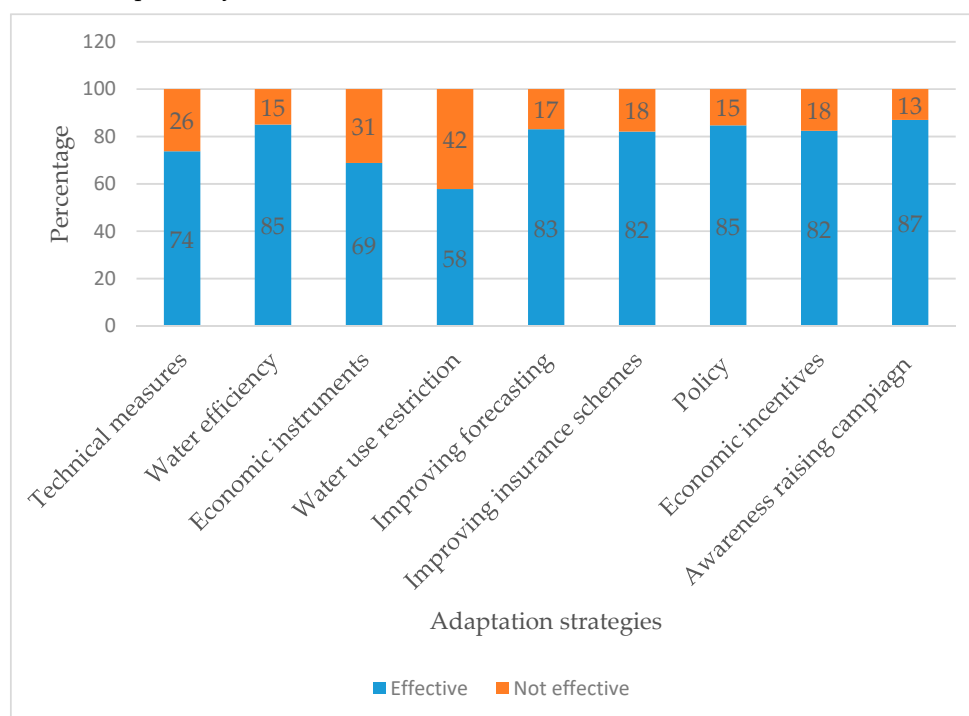


Figure 4. Effectiveness of different adaptation measures. Source: authors' calculations.

The results in Figure 4 show that most of the adaptation strategies were effective in the study area. However, the need for the implementation of these adaptation strategies varied from farmer to farmer and from one community to another. This observation demonstrates that sustainable

development to help reduce vulnerability needs to be undertaken concurrently with adaptation for it to be successful [59,60].

4.4. Factors Influencing the Choice of Adaptation Measures

The multinomial probit model was used to examine the factors that influenced the respondents' choice of effective adaptation measures during the drought in Thaba 'Nchu. In order to cope with the effects of drought, the respondents adopted different measures on the basis of their limited household and external resources. Tables 4 and 5 present model estimates of the factors influencing the respondents' choice of adaptation strategies. The coefficients are explained at the 1%, 5%, and 10% levels of significance. The results include the following coping strategies: technical measures to increase supply, increasing efficiency of water use, economic instruments/external costs, restriction of water use, improving forecasting, and improving one's insurance schemes.

Table 4. Estimates of the multinomial probit model on the choices of effective adaptation strategies.

Explanatory Variable	Technical Measures		Water-Use Efficiency		Economic Instruments	
	Coefficient	Z-Value	Coefficient	Z-Value	Coefficient	Z-Value
Constant	0.280	0.31	5.713 ***	5.95	0.036	0.04
Gender	0.033	0.18	−0.132	−0.64	0.086	0.50
Age	−0.002	−0.29	−0.010	−1.35	0.011 *	1.76
Household size	−0.014	−0.32	−0.006	−0.13	−0.047	−1.14
Off-farm business	−0.060	−0.31	0.214	1.02	−0.191	−1.05
Drought frequency	0.055	0.73	0.179 **	2.02	0.125 *	1.75
Farm training	0.727 **	2.06	−0.004	−0.01	−0.279	−0.92
Primary education	−0.488	−1.18	0.034	0.08	0.348	0.89
Secondary education	−0.069 ***	−0.36	0.149	0.67	0.003	0.02
University degree	0.570	1.61	0.273 ***	0.75	0.391	1.32
Marital status	−0.051	−0.28	−0.116	−0.57	−0.252	−1.44
R2001–R5000	1.004	1.57	−4.382 ***	−8.78	0.483	0.72
R5001–R10,000	1.774 ***	2.57	−4.058 ***	−6.26	0.950	1.37
R10,001–R20,000	1.849 ***	2.36	−4.768 ***	−7.48	1.493 *	1.83
Human capital index	0.066 ***	0.64	0.096	0.76	0.045	0.44
Social capital index	0.039	0.33	−0.119	−0.93	0.080	0.73
Economic capital index	−0.051	−0.35	0.484 *	2.76	−0.361 ***	−2.40
Institutional capital index	−0.214	−1.50	−0.330	−2.11	0.018	0.13
Natural capital index	0.207	1.76	0.213 *	1.75	0.287 ***	2.42
Political capital index	−0.295 **	−2.18	−0.319	−2.26	−0.264 **	−2.05
Number of observations			294			
Wald chi ² (19)			443.95 ***			
Log-likelihood			−544.55			

* = significant at 10%, ** = significant at 5%, *** = significant at 1%. Source: authors' calculations.

Gender is an important variable affecting adoption decisions at the farm level. The variable gender was significant and negatively influenced farmers' choice of water-use restriction as a coping strategy. This implies that female respondents were less likely to adopt water-use restriction as a coping/adaptation strategy. These findings are consistent with Deressa et al. [51] and Mandleni and Anim [56], who found that male-headed households adapted more readily to climate change. The age of the respondents was significant and had a positive influence on the choice of economic instruments (e.g., water pricing) and water-use restriction as coping strategies. This means that the older the respondent, the more likely he/she was to adapt economic instruments and water-use restrictions as coping strategies. This is in line with the findings of Ishaya and Abaje [61] and Maddison [62].

Seasonal farming was significant and had a negative influence on improving one's insurance scheme as a coping strategy. This implies that respondents who were seasonal farmers were less likely to adapt improving one's insurance as a coping strategy. Hassan and Nhemachena [52] have shown that a warmer winter and spring promotes switching to the use of irrigation, multiple

cropping, and mixing crop and livestock activities, especially under irrigation. Drought frequency was significant and had a positive influence on improving forecasting, water-use efficiency, and economic instruments. This implies that, when droughts became more frequent, the respondents were more likely to adopt water-use efficiency, improving forecasting and economic instruments as coping strategies. The findings are consistent with Anim [63], Araya and Adjaye [64], Gould, Saupe, and Klemme [65], and Traoré, Landry, and Amara [66], who found that farmers' awareness and perceptions positively and significantly affect their decisions to adopt coping measures.

Farming skills were significant and had a positive influence on technical measures. This implies that respondents with farming skills were more likely to adopt technical measures as a coping strategy, as the skills learnt while farming enabled them to know what technical measures they had to apply. This is consistent with the findings of Hassan and Nhemachena [52]. Primary education, secondary education, and a university degree were significant and had a positive influence on all six coping strategies compared to no education. Of all the significant variables, secondary education was negatively related to technical measures, while all the other variables were positively related. This implies that any form of education was important for the respondents to make informed decisions on which adaptation strategy to choose. The findings are consistent with the work of Deressa et al. [51], Igoden, Ohoji, and Ekpere [67], Lin [68], Maddison [62], Norris and Batie [69], and Ogunniyi [70], who found that education increased the probability of adaptation to climate change.

Marital status was significant and had a negative influence on water-use restriction as a coping strategy. This implies that respondents who were married were less likely to adopt water-use restriction as a coping strategy. The finding is consistent with Mudombi [15], who found that marital status negatively correlated with responsiveness. Income in the brackets R2001 to R5000, R5001 to R10,000 and R10,001 to R20,000 was significant and had both a positive and negative influence on all six coping strategies. Income between R2001 and R5000 had a positive influence on improving forecasting as a coping strategy. Furthermore, income between R2001 and R5000 had a negative influence on water-use efficiency and improving one's insurance scheme as coping strategies. These results show that respondents had to have an income in order to adopt improving forecasting as a coping strategy. A monthly income of R5001 to R10,000 had both positive and negative influences on water-use efficiency, improving forecasting and improving one's insurance scheme. Technical measures and improving forecasting were positively related, whereas water-use efficiency and improving one's insurance scheme were negatively related. These results show that an income of between R5001 and R10,000 was important for adopting water-use efficiency and improving one's insurance scheme as coping strategies.

A monthly income of between R10,001 and R20,000 had a positive influence on technical measures, water-use efficiency, improving one's insurance scheme, economic instruments, and improving forecasting. This is consistent with Alam [71], who found that a unit increase in household income significantly increased the probability of adoption of a coping strategy. Of all the variables that were significant, water-use efficiency and improving one's insurance scheme were negatively correlated, while the others were positively correlated. This implies that respondents with a monthly income of R10,001 to R20,000 are less likely to adopt improving one's insurance scheme and water-use efficiency as coping strategies and more likely to adopt improving forecasting, economic instruments, and technical measures as coping strategies. It therefore shows that it costs money for the respondents to be able to adopt certain coping strategies. This finding is consistent with Mdungela, Bahta, and Jordaan [72], who found that income helped farmers adapt to more than one coping strategy.

Table 5. Estimates of the multinomial probit model on the choices of effective adaptation strategies (continued).

Explanatory Variables	Water-Use Restriction		Improving Forecasting		Improving One's Insurance Scheme	
	Coefficient	Z-Value	Coefficient	Z-Value	Coefficient	Z-Value
Constant	0.171	0.19	−0.744	−0.80	6.222 ***	6.36
Gender	−0.314 **	−1.89	−0.146	−0.74	−0.296	−1.52
Age	0.012 **	2.04	0.009	1.34	−0.002	−0.35
Household size	−0.018	−0.44	0.007	0.17	−0.027	−0.60
Off-farm business	−0.228	−1.27	−0.270	−1.28	−0.561 **	−2.41
Drought frequency	−0.014	−0.20	0.184 **	2.15	−0.039	−0.48
Farm training	−0.428	−1.44	0.305	0.86	0.487	1.15
Primary education	0.736 *	1.70	0.452	1.06	−0.493	−1.27
Secondary education	0.026	0.14	0.198	0.89	−0.089	−0.41
University degree	−0.060	−0.22	0.650 ***	1.95	0.282	0.72
Marital status	−0.381 **	−2.28	0.095	0.48	−0.010	−0.04
R2001–R5000	−0.428	−0.65	1.334 **	2.10	−4.139 ***	−7.67
R5001–R10,000	−0.155	−0.22	1.663 ***	2.45	−3.174 ***	−4.41
R10,001–R20,000	−0.503	−0.68	1.957 **	2.40	−3.536 ***	−5.15
Human capital index	−0.083	−0.83	−0.182	−1.56	0.114	0.95
Social capital index	0.156	1.53	0.146	1.14	−0.009	−0.07
Economic capital index	0.168	1.19	0.004	0.02	0.017	0.11
Institutional capital index	−0.225	−1.62	−0.284 *	−1.83	−0.198	−1.43
Natural capital index	0.098	0.89	0.346 ***	2.77	0.271 **	2.31
Political capital index	0.012	0.10	−0.140	−0.94	−0.368 ***	−2.72
Number of observations	294					
Wald chi ² (19)	349.06 ***					
Log-likelihood	−534.52					

* = significant at 10%, ** = significant at 5%, *** = significant at 1%. Source: author's estimation.

The human capital index was significant and had a positive influence on technical measures as a coping strategy. This implies that human capital factors influenced respondents to adopt technical measures as a coping strategy. The economic capital index was significant and had a positive influence on water-use efficiency and a negative influence on economic instruments as coping strategies. This implies that economic factors contributed to the respondents' choice to adopt water-use efficiency as a coping strategy.

The institutional capital index was significant and had a negative influence on improving forecasting as a coping strategy. The negative sign of the estimated coefficient for improving forecasting implies that respondents were less likely to adopt improving forecasting as a coping strategy. The natural capital index was statistically significant and had a positive influence on economic instruments and improving one's insurance scheme. This implies that respondents were more likely to adopt economic instruments, improving one's insurance scheme, and water-use efficiency as coping strategies. The fitted variable (constant) was statistically significant and had a positive influence on improving one's insurance scheme and water-use efficiency as coping strategies. This implies that the respondents were more likely to adopt water-use efficiency and improving one's insurance scheme.

5. Conclusions

This study examined smallholder farmers' adaption to drought in Thaba 'Nchu. Effective adaptive strategies and measures were identified, as well as the vulnerability across different capitals. The respondents' human capital vulnerability to drought in Thaba 'Nchu was very high compared to their economic and social vulnerability. Influences such as age, gender, and marital status contributed towards human capital vulnerability. Different indicators contributed differently to

drought vulnerability. The respondents were vulnerable to drought because they did not have enough resources to assist them during drought periods.

The majority of the respondents used water-use restriction as a coping strategy during drought periods. There were several reasons for this, such as the resources available, the effective coping strategy for that specific location/area, and the socio-economic status of the respondents. The government's inadequate contribution to drought risk reduction, the age of the respondents, the monthly income of each household, and the inequality of decision-making powers between male and female respondents were also found to contribute greatly to choosing an effective adaptation strategy. The government was perceived to be active mainly in response. Government support was referred to as inefficient and not accessible by everyone. Respondents in Thaba 'Nchu did not implement many coping strategies; however, they considered a number of them to be effective/necessary.

Policymakers should aim at improving and implementing those coping strategies that farmers deem necessary in order for farmers to have more options for coping strategies in the future. The Department of Agriculture should consider training smallholder farmers and providing resources that will enhance knowledge of other available coping strategies. Farmers who are better educated and skilled stand a better chance of coping with drought. Therefore it is recommended that policymakers should ensure that a government programme is implemented in order to help farmers with off-farm training, which will assist them in preparing for drought and help them with decision-making processes during periods of drought.

Our study reveals that the inclusion of vulnerability capitals in climate adaptation choice models presents meaningful insights that are needed for policy design and measures aimed at assisting vulnerable farmers in periods of drought. Therefore, future studies should consider estimating the vulnerability status of farmers and investigating its impact on their choice of climate-related adaptation strategies. The study is not without limitations. Firstly, the study was conducted in the Free State province of South Africa. Therefore, future studies should examine the effectiveness of the identified adaptation strategies and coping measures in other provinces of South Africa. Secondly, the study focused only on smallholder farmers, and we therefore suggest that future work should replicate the study among medium- and large-scale farmers to ascertain whether their effective adaptation and coping measures are similar to or different from those of smallholder farmers.

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