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Factors affecting smallholder subsistence farmers' drought adaptation and resilience: a case study from northern-central Namibia

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ABSTRACT
A large proportion of households in northern Namibia rely on agriculture for livelihoods, yet the area is highly susceptible to drought shocks. Therefore, these households must employ strategies to adapt and mitigate the consequences of drought. This study aimed to identify factors affecting smallholder subsistence farmers' vulnerability and adaptation to drought in Oshipya District, Etayi Constituency, Omusati Region in northern-central Namibia (NCN). Data on drought *ex-ante* and *ex-post* coping mechanisms and sociodemographic characteristics were collected from 80 randomly selected smallholder farmers using a structured questionnaire. Levels of drought resilience and vulnerability were estimated using a Rasch model. Farmers were categorised according to asset ownership using a multivariate cluster analysis technique, while a principal component analysis was used to estimate wealth scales. Furthermore, a general linear model was employed to assess factors affecting variability in household vulnerability and resilience to drought shocks. Gender of household head, marital status, membership of a farming organisation, household size, type of farming activities and farm size significantly affected farmers' drought resilience levels. Combined crop-livestock farmers were more resilient than livestock or crop farmers while the level of drought adaptability increased with the size of the farm, years of farming experience and membership of a farming organisation. On the other hand, household size significantly affected vulnerability levels, with large households being more susceptible to the effects of drought. We encourage farmers to diversify their farming activities, diversify sources of livelihoods and join farming organisations to gain knowledge on drought mitigation. Furthermore, smallholder farmers should be better prepared for drought through infrastructure development, training, and provision of support services to make them self-reliant and hence reduce government expenditure on drought relief programmes.

Keywords: coping mechanisms; drought; Namibia; resilience; smallholder farmers; vulnerability

INTRODUCTION

Northern-central Namibia (NCN) is semiarid, characterised by high temperatures, low rainfall and prolonged dry seasons (Davies 2017, Shikangalah 2020) with exceedingly high evaporation rates above 3,000 mm per annum (Koeniger *et al.* 2021, World Bank Group [WBG] 2021). The Namibian climate is becoming increasingly hotter and drier (Davies 2017) and droughts and other climate-related hazards are prevalent and becoming more worrisome to rural communities that rely on agriculture as a livelihood source. These hazards render crops and livestock less productive (Angula & Kaundjua 2016, Davies 2017, Nangolo & Alweendo 2020). Drought is defined as a prolonged period of no to low rainfall that leads to water shortage, causing detrimental effects on the productivity of land, food and feed security, thus affecting human, animal and plant life.

In this study, **drought coping strategies** refer to a set of short-term measures households adopt in response to immediate and irregular decline in access to food, water and feed due to drought consequences, and make short- and long-term contingencies in preparation for future droughts. Drought adaptation means anticipating and taking appropriate actions to prevent or minimise the adverse effects of drought (European Commission [EU] 2016). **Resilience** focuses on preparing communities for future drought, employing means to endure, withstand and recover from such events (Department of Environmental Protection 2022, Mehryar 2022) and measures a household's ability to employ risk reduction measures to guard against the devastating effects of drought shocks. On the other hand, maladaptation refers to actions intended to reduce the impacts of drought and other climate change hazards that actually create more risks and vulnerability (Beddow 2022). **Vulnerability** is defined by Pachauri *et al.* (2014) as a function of adaptive capacity and propensity or predisposition to be adversely affected, and it gives a measure of the crisis control mechanisms that households utilise to mitigate

shocks after a drought has already occurred which might put them at risk if they affect their socioeconomic status. Such measures mainly have negative effects on the economic status of households as they may have to resort to disposal of productive assets.

Although Namibia is susceptible to drought, agriculture is still one of the main livelihood sources, with more than 70% of the Namibian population directly or indirectly relying on it (MAWF 2015, GIZ 2022). The country's agricultural sector is dominated by livestock farming, followed by crop farming, and the economy is heavily dependent on agricultural products, which contribute between 4% and 6.6% to the Gross Domestic Product (GDP) (excluding contribution from fish) (GIZ 2022, MeatCo 2022) making the sector a vital source of livelihood through employment creation, food security, income generation and poverty alleviation. Due to climate change, most subsistence farmers in NCN no longer produce sufficient crops to last until the next harvesting season (MAWF 2015).

Farmers in Omusati, Ohangwena, Oshikoto and Kavango regions rely predominantly on subsistence production in addition to salaries and wages (Nyadinga 2012, NSA 2018). Frequent droughts have decimated livestock and also led to crop failures. The effects of drought are worsened by the fact that subsistence farming households are mainly reliant on rain-fed agriculture (Ndlovu 2009, African Adaptation Project 2010). Because of high incidents of drought in the northern parts of Namibia, it is important for these communities to be able to prepare for and cope with consequences of drought (GIZ 2022).

Due to reoccurring droughts and other climate change hazards within the country, the Namibian government developed a National Climate Change Policy (MET 2011) which elaborates on climate change adaptation in Namibia, as well as the National Climate Change Strategy and Action Plan (NCCSAP) (MET 2015) aimed at guiding national activities and measures to mitigate climate change hazards. These policies encourage individual farmers to adopt self-reliant approaches to drought risk mitigation to reduce overdependence on aid from the government and other non-governmental relief agencies, with financial assistance and food interventions only to be considered in the event of an extreme drought. Some community-based adaptation programmes such as the five-year (2015–2019) Scaling Up Community Resilience to Climate Variability and Change in Northern Namibia, were implemented by non-governmental organisations in liaison with the then Ministry of Agriculture, Water and Land Reform (MAWLR), the Ministry of Environment and Tourism (MET), Regional Councils and Traditional Authorities to address drought and water scarcity, land degradation and deforestation; and planting of flood and drought-resistant crops to enhance agricultural production and food security. After such interventions very few studies have, however, been done to assess the level of adaptation and resilience to drought and to evaluate the factors that might affect households' ability to cope.

The factors that affect farmers' ability to adopt drought coping mechanisms need to be evaluated as this might guide policy formulation and implementation. Angula & Kaundjua (2016) applied a Climate Vulnerability and Capacity Analysis (CVCA) framework (CARE International 2019) and social vulnerability approach to assess the factors contributing to subsistence farmers' vulnerability to impacts of climate change in the regions within NCN (Ohangwena, Oshana, Oshikoto and Omusati). Their findings revealed that households have low levels of adaptation and mitigation due to a combination of cultural, social and political factors; overreliance on rain-fed subsistence agriculture; adult and elderly population; high levels of unemployment; and lack of land tenure. The coping strategies implemented by households in the NCN included destocking, selling livestock to buy food, nomadic pastoralism, planting of drought-resistant crop varieties, reliance on government disaster response, supplementing agricultural activities with income generation, remittances and pensions funds. However, no long-term coping mechanism was observed. Angula & Kaundjua (2016) recommended that future research should apply CVCA and vulnerability indices to contextualise vulnerability assessment at local and household level, including more gender disaggregated research.

Several studies on drought coping strategies have been undertaken in southern Africa. Mdungela *et al.* (2017) used a Multinomial Probit Model to determine the factors affecting the choice of drought coping strategy. Destaw & Fenta (2021) analysed the determinants of farm level adaptation measures in Africa using a Multinomial Logit Model, while Rakgase & Norris (2014) applied this model to assess the factors affecting household use of adaptation strategies in South Africa. Uddin *et al*. (2014) rejected the Linear Probability and Probit Models in favour of a Logistic Model and assessed the factors affecting household use of adaptation strategies in South Africa and Bangladesh, respectively. One weakness of multinomial choice models is that they present different coping strategies as possible response options of a single multi-category question. However, one household may employ more than one coping mechanism and this might make modelling challenging. Those who applied a binary logistics model might therefore need a separate model for each

coping strategy. To the best of our knowledge, no study has estimated resilience and vulnerability levels on a continuous continuum as well as determining the factors that affect a household's ability to cope with drought based on such a measure. The current study applied statistical modelling to rank a household's ability to adapt to drought coping mechanisms on a continuous scale, exploring the factors that are influential in the household's choice of coping mechanisms.

METHODS

Study area and data collection

The case study was conducted in Oshipya District, Etayi Constituency, situated in north-central Namibia, approximately 60 km northwest of Oshakati (Figure 1). Data were collected through a cross-sectional survey in September 2020, after the 2019/2020 drought. The Omusati Region was selected since it has the highest proportion of the population reliant on subsistence farming (NSA 2018) and is highly susceptible to drought and other natural shocks. The dry season lasts from May to October, and the rainy season extends from November to April (Hiyama *et al.* 2017). The targeted population comprised of approximately 260 small-scale farming households in nine villages. Eighty (80) households were randomly selected from five of the nine villages randomly selected for the study. This study extends a preliminary analysis of this data set presented in Charamba *et al.* (2021).

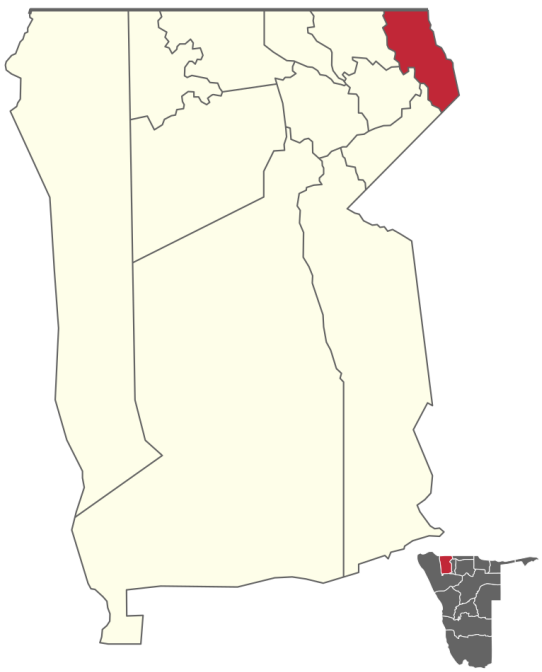

Figure 1: *Etayi Constituency (red) in Omusati Region (yellow) in Namibia (grey). Source: NordNordWest (2019).*

Estimation of resilience and vulnerability levels

The study analysed data collected through the administration of a structured questionnaire covering aspects of household socioeconomic and demographic characteristics, *ex-ante* adaptation coping strategies and *ex-post* maladaptation coping strategies employed to guard against the effects of drought (Appendix 1). *Ex-ante* coping strategies are those strategies employed by households to reduce the risk of drought *a priori*, that is, before the drought has occurred, while *ex-post* strategies are *a posteriori* strategies employed by households to mitigate the risk of the drought that has already occurred; these may cause additional risks to the households. The *ex-ante* strategies included: planting of drought-resistant crops; crop diversification to spread the risk; conservation agriculture; fencing of grazing areas and water sources; planting of fruit trees; irrigation of crops; preservation of pearl millet stalks to use as animal feed during times of drought; and livelihood diversification such as owning a small shop. The *ex-post* coping strategies included: the dispersal of family members; seeking and eating wild and unpreferred foods; disposal of productive assets and livestock to buy food; and borrowing and begging from neighbours.

The household drought resilience and vulnerability levels were measured as latent variables on an interval continuum from the *ex-ante* and *ex-post* coping strategies, respectively by employing a two-parameter logistic (2PL) regression Item Response Theory (IRT) model (see Charamba *et al.* 2021). The scales were measured with an arbitrary zero (0) midpoint and the unit of measurement of one (1) ranging from $-\infty$ to $+\infty$ although the practical application measurements are usually between -3 (very low) and +3 (very high) (Tommy & Udo 2019, Columbia University 2022). In this study the scale was continuous, ranging from -4 (poor) to 4 (high) with an expected average of 0. The theory is based on the notion that different items (coping strategies) have different levels of difficulty, that is, some are easily implemented and some are more difficult to do.

Data analysis

An unsupervised hierarchical cluster analysis was employed to categorise households according to assets and livestock ownership while principal components analysis (PCA) was used to derive indices for livestock and assets ownership on a continuum, where the first principal component was used for further analysis. A general linear model (GLM) was used to assess the household sociodemographic and socioeconomic factors that affect household vulnerability and resilience to drought shocks. Partial eta-squared (see Zach 2021) and Cohen's f effects size (Cohen 2013) were used to quantify the magnitude of the differences between category means. Cohen's effect size was employed as

it quantified the magnitude of the effect size beyond the p-value which can lead to the conclusion that the effects are significant without quantifying them. The effect size takes on value 0 (zero) when the null hypothesis cannot be rejected and a non-zero value when the null hypothesis is rejected and hence it serves as an index of the degree of departure from the null hypothesis. The proportion of variance in the dependent variable explained by the factor (Partial eta-squared, η^2) was computed using equation (1):

$$(1)\ \eta^2 = \frac{SS_{Between(effect)}}{SS_{Between(effect)}+SS_{Error}} = \frac{SS_{Between(effect)}}{SS_{Total}}$$

where SS is Sum of Squares. For example, a value of $\eta^2 = 0.15$ implies that 15% of the total variability can be accounted for by that variable. Cohens f effect size was then calculated using equation (2):

$$(2)\ f = \sqrt{\frac{\eta^2}{1-\eta^2}}$$

Effect sizes less than 0.10 are considered non-significant while effects between 0.10 and 0.24 are considered small. Effects between 0.25 and 0.40 are medium sized while those above 0.40 are large effects (Cohen 2013).

RESULTS

Sociodemographic characteristics of respondents

Tables 1 and 2 show the descriptive statistics of sociodemographic and socioeconomic characteristics of respondents, respectively.

Most households were headed by males (male = 63.8%; female = 36.4%); the respondents were largely not married (75%) and majority had at least primary education (83.7%).

The results in Table 2 show that 68.8% of the sampled households practiced mixed farming; 85% of the respondents had farming experience of at least 5 years; the majority (57.4%) owned 3 ha of land or more; and all respondents had additional sources of livelihood besides agriculture. Most households (85%) owned some assets such as cars, wheelbarrows, and livestock; about 10% of households had disposed of their assets to buy food in a drought period.

Household resilience and vulnerability levels

Figure 2 shows the household resilience and vulnerability levels estimated using the 2PL model.

The sample estimates of the household levels of vulnerability to effects of drought ranged from -2.93 (the least vulnerable) to 3.21 (the most vulnerable) relative to the group with an average of -0.64 ± 0.17 (mean ± SE). Household resilience levels ranged

Table 1: *Sociodemographic characteristics of respondents to a structured questionnaire in northern-central Namibia (n = 80).*

Characteristic	Number	Percentage
Age of respondent		
25–34	5	6.3
35–44	15	18.8
45–54	11	13.8
55–64	23	28.8
65+	26	32.5
Gender		
Male	51	63.8
Female	29	36.3
Marital status		
Married	20	25.0
Single	33	41.3
Widowed/widower	27	33.8
Level of education		
None	13	16.3
Primary	39	48.8
Matric	7	8.8
Tertiary	21	26.3
Household size		
0–4	29	36.3
5–8	39	48.8
9–12	12	15.0
25–34	5	6.3

Table 2: *Socioeconomic characteristics of respondents to a structured questionnaire in northern-central Namibia (n = 80).*

Characteristic	Number	Percentage
Farming experience (years)		
0–4	12	15.0
5–14	13	16.3
15–24	10	12.5
25–34	17	21.3
35–44	9	11.3
45+	19	23.8
Farm size (ha)		
< 1	3	3.8
1–2	31	38.8
3–5	19	23.8
6+	27	33.8
Type of farming activities		
Livestock production	2	2.5
Mixed farming	55	68.8
Crop husbandry	23	28.8
Off-farm activities		
Formal employment	9	11.3
Non-formal	40	50.0
Pension/remittances	27	33.3
Plant fruit trees	17	21.3
Own small shop	3	3.8

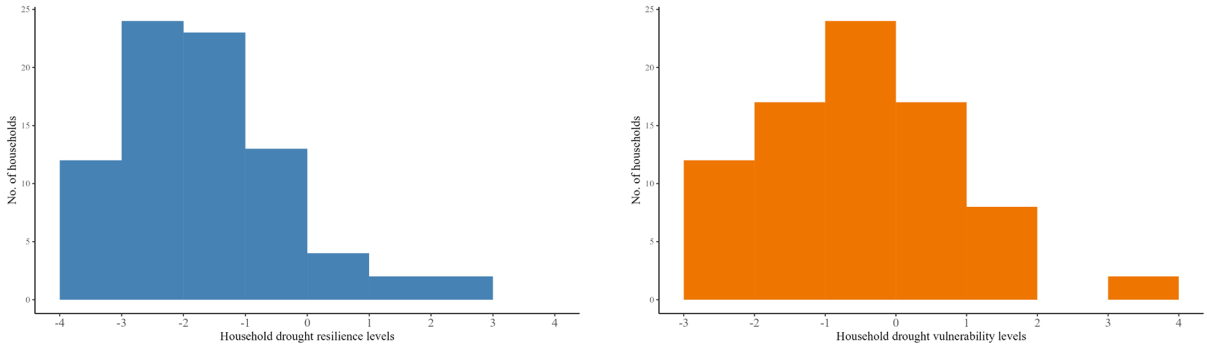

Figure 2: *Distribution of the level of resilience (left) and vulnerability (right) to drought of 80 households in northern-central Namibia measured as latent variables on an interval continuum from the* ex-ante *and* ex-post *coping strategies, respectively by employing a two-parameter logistic (2PL) regression Item Response Theory (IRT) model.*

from -3.32 (less resilient) to 2.22 (most resilient) relative to the group (-1.46 ± 0.14; mean ± SE). About 75% of the respondents were ranked below zero on the resilience/preparedness continuum. On the other hand, about 35% of the households were ranked above zero on the vulnerability scale.

Figure 3 shows the scree plot of eigenvalues and the variables plot for the variables used in computation of the first principal component (livestock index). The first principal component accounted for 36% of the variation. All the variables are positively correlated as they point in the same direction (positive) although sheep ownership is not strongly related to the other livestock and contributed more variation.

From the results shown in the scree plot in Figure 3, the first principal component for assets PCA, used as the asset index in the GLM, accounted for about 35% of the total variation. Mobile phone, TV and wheelbarrow ownership contributed more to the principal components.

Factors affecting household resilience and vulnerability to drought

A weak Pearson correlation coefficient of -0.092 was observed between household vulnerability and resilience levels. Table 3 gives the results for the factors affecting household resilience and vulnerability to drought.

Membership of a farming organisation, gender of household head, type of farming activities, household size and asset ownership all had a significant impact on the variation in households' levels of resilience to effects of drought (Table 3). Membership of a farming organisation had a large effects size ($f = 0.43 > 0.40$) while the type of farming activities had medium effect size ($f = 0.25 \leq 0.29 \leq 0.40$). The marital status and gender of household head, household size and years of farming experience had smaller effect sizes ($0.10 \leq f \leq 0.24$). On the other hand, awareness of the impeding drought and level of education were among the factors that were not significant ($f < 0.10$) in the model.

Table 3: *Factors affecting households' resilience and vulnerability to drought in northern-central Namibia (n = 80).*

	Resilience		Vulnerability	
Factor	**Partial Eta Squared (η^2)**	**Cohen's f**	**Partial Eta Squared (η^2)**	**Cohen's f**
Gender of household head	0.050	0.23*	0.005	0.07
Marital status of household head	0.005	0.13*	0.001	0.03
Membership to farming organisation	0.158	0.43***	0.023	0.15*
Type of farming activities	0.080	0.29**	0.030	0.18*
Drought awareness	0.007	0.08	0.002	0.05
Farm size	0.001	0.03	0.003	0.05
Age of household head	0.002	0.05	0.001	0.03
Household size	0.026	0.16*	0.058	0.25**
Years of farming experience	0.023	0.15*	0.042	0.21*
Asset index	0.003	0.06	0.078	0.29**
Livestock index	0.004	0.06	0.011	0.11
Years of education	0.006	0.08	0.016	0.13*

small effect size; ** medium effect size; * large effect size.*

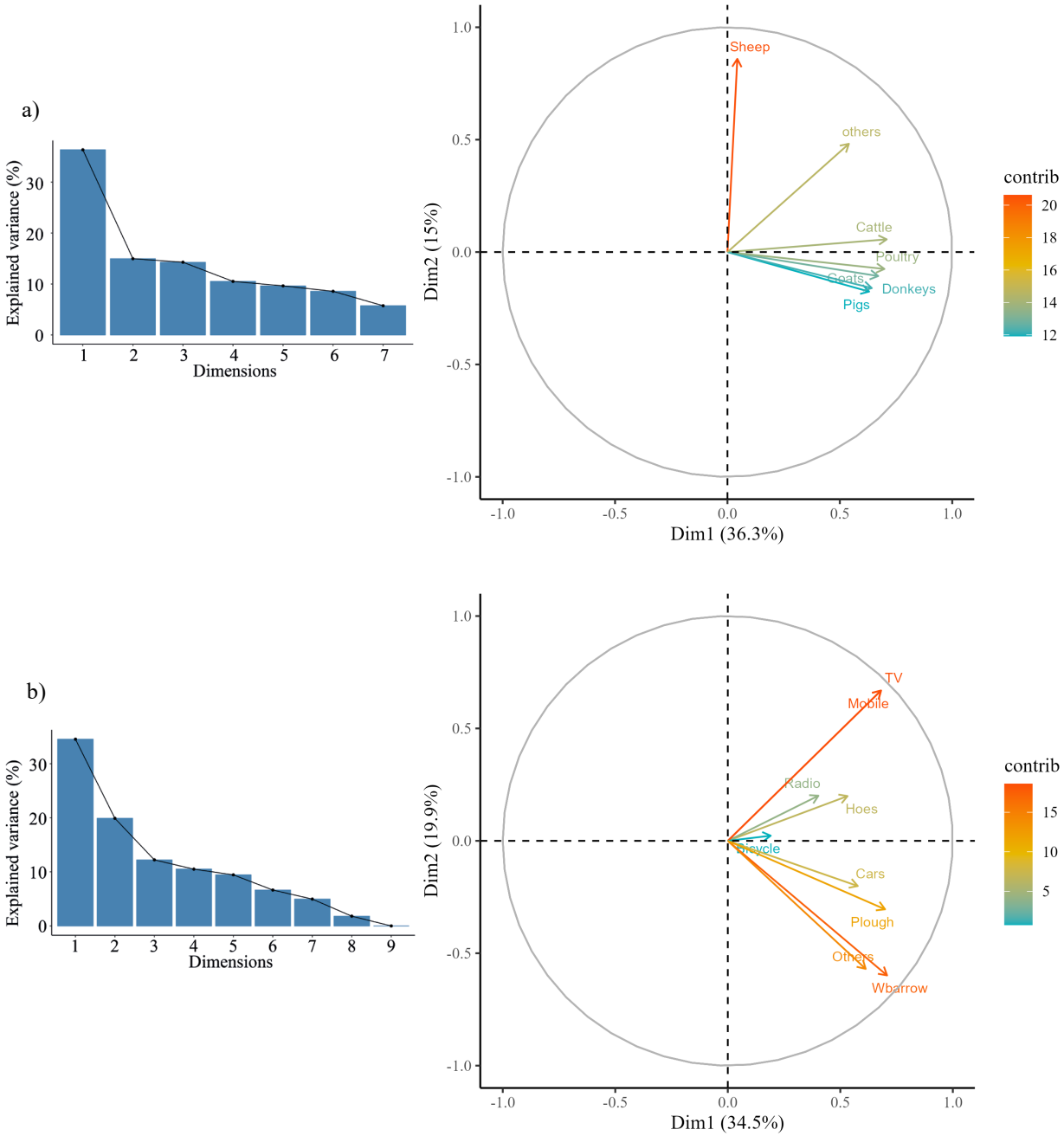

Figure 3: *Principal components analysis scree plots and variable biplots for the computation of a) livestock index and b) assets index.*

Appendix 2 gives the model parameter estimates from the GLM. The regression coefficients indicate that male farmers were more resilient than female farmers ($B = 0.558$) while married farmers were more resilient than single farmers ($B = 0.337$). Farmers belonging to a farming organisation were 2.482 units more resilient than those who did not. Increase in household size ($B = 0.060$) and increase in farming experience ($B = 0.016$) increased household resilience to drought.

The factors that affected households' vulnerability to drought are shown in Table 3. Membership of a farming organisation, type of farming activities, household size, years of farming experience, livestock index, asset index and years of education significantly affected household levels of vulnerability with small to medium effect sizes ($0.1 \leq f \leq 0.4$).

Appendix 3 shows the GLM parameter estimates (B) for households' vulnerability to drought. Farmers who do not belong to a farming organisation were more vulnerable to drought ($B = 1.099$) than farmers who did belong to one. Furthermore, livestock farmers ($B = -1.663$) were less likely to be vulnerable

Table 5: *Comparison of resilience and vulnerability levels of households employing different types of drought coping strategies in northern-central Namibia (n = 80).*

	Resilience		Vulnerability	
Livelihood strategy	**Mean**	**Standard error**	**Mean**	**Standard error**
Borrow	-3.32[a]	0.18	-1.77[a]	0.26
None	-2.13[a]	0.20	-0.99[a]	0.31
Own a small shop to earn money	-1.26[ab]	0.54	-0.69[a]	0.38
Preserve pearl millet stalks for animals	-0.93[b]	0.00	-0.61[a]	1.16
Plant fruit trees to eat.	-0.90[b]	0.36	-0.52[a]	0.41
Partial eta squared (η^2)	0.265		0.009	
Cohen's f	0.60		0.09	

[ab] Means with different superscripts differ significantly

compared to crop and mixed crop-livestock farmers. Increase in household size increased ($B = 0.117$) vulnerability, while increase in asset ownership ($B = 0.442$) and increase in years of education reduced ($B = 0.040$) vulnerability levels. However, when the livestock herd increased, vulnerability increased ($B = 0.042$).

Information dissemination

The results indicate that 72.5% of the respondents were aware that there was going to be a drought in 2019 while 27.5% claim not to have had prior knowledge of the upcoming drought. Table 4 gives the media sources that the households used to obtain weather and climate change awareness information disseminated by the meteorological services department. Approximately 30% of the respondents had no access to meteorological information and 87.5% of these households were often not aware of the forthcoming drought.

Diversification of farming activities

A significant proportion (61%) of the sampled households did not diversify their livelihood sources in preparation for the forthcoming drought of 2019, while about a third preserved pearl millet stalks to use as animal feed. Some households also planted fruit trees to support long-term resilience. Few households diversified livelihoods by owning a shop and/or borrowed money and food supplies from neighbours. Results from one-way analysis of variance (ANOVA) (Table 5) showed a significant ($f = 0.60 > 0.40$) difference in the resilience levels for different livelihood activities although the difference between the vulnerability levels was not significant ($f = 0.09 < 0.10$). The results show that it was the least resilient households (mean = -3.32) and more vulnerable households (mean = -1.77) that resorted to borrowing when drought occurred.

DISCUSSION

Factors affecting smallholder farmers' resilience and vulnerability to drought

Male farmers, farmers who are members of farming organisations, livestock farmers, large households, married farmers and farmers with more farming experience were more resilient to drought than their counterparts (Cohen's f effect sizes ranging from small to large effects). On the other hand, households with more years of farming, farmers with more years of education and farmers with more assets are less vulnerable to drought. However, large families and families with more livestock are more vulnerable to drought consequences when the drought has already occurred. The results from the ANOVA revealed that resilience levels were significantly affected by livelihood activities, although the difference between the vulnerability levels was not significant. More vulnerable households and households that were less resilient to drought resorted to borrowing to mitigate consequences of drought.

Table 4: *Media sources utilised by households in northern-central Namibia for receiving drought awareness information (n=80).*

Medium	**Households using media (%)**	**Households using media being aware of impending 2019 drought (%)**
None	30.0	12.5
Television	3.8	33.3
Radio	37.5	100
Newspaper	1.3	100
Friends and family	6.3	100
Cellphone messages	21.3	100

Household size

The size of the household influenced resilience to drought, with larger households being more resilient. These results were in agreement with Deressa *et al*. (2010), Opie (2011) and Marie *et al*. (2020) who argued that households with large family sizes were more likely to adopt and use more intensive coping strategies because they had a greater labour pool. Tazeze *et al*. (2012), on the contrary, observed household size to negatively affect coping mechanism adoption and adaptation to climate change, attributing the negative effect to the higher likelihood for the large families to be compelled to divert part of their labour force to off-farm activities in an attempt to earn more income, and in order to ease the consumption pressure. This apparent contradiction in results might be related to different analysis methods used. Nyangena (2008) conducted a study in rural Kenya and concluded that large families can practice multiple cropping and diversify their cropping varieties whereas smaller families tend to be restricted to monocropping with a livestock activity. However, the current study shows that if a drought has already occurred, larger households were more vulnerable, most likely because they require more food resources.

Gender of household head

The gender of the household head had a significant effect on drought resilience with male-headed households being more resilient compared to their female-headed counterparts. This concurs with the findings from other studies that show that male-headed household members were more risk averse and had more access to information, land and other resources, had a better appreciation of climate change and hence had higher likelihood of adopting drought coping strategies than their female counterparts (Ajao & Ogunniyi 2011, Ofuoku 2011, Opie 2011, Tazeze *et al.* 2012, Legesse *et al*. 2013). Gender was also noted by Angula & Menjono (2014) and Angula & Kaundjua (2016) to significantly affect the levels of vulnerability for households in the northern regions of Namibia. Their study noted that men had more access to information and had more technical skills in some cases due to having been employed on commercial farms.

Angula & Menjono (2014) and Angula *et al.* (2021) reiterated that climate change impacts are not gender neutral. Women and men are not equally vulnerable to climate change effects and their adaptive capacities are different. Angula *et al*. (2021) reiterated that gender-blind climate change initiatives could exacerbate existing gender inequalities and undermine sustainable climate change activities, pointing to gender imbalances in leadership and inequalities in local community resource management as some of the causes. As such, they proposed that for climate change resilience to be achieved, gender mainstreaming and women empowerment in community-based climate change and adaptation interventions should be encouraged. Conversely, Moyo *et al*. (2013) found that gender of household head had no effect on household ability to employ drought coping mechanisms. In the current study, gender did not significantly affect vulnerability levels to a drought that had already occurred.

Farm size

Farm size did not significantly affect a household's choice of drought coping strategies. These results contradict results from several other studies (Ajao & Ogunniyi 2011, John *et al*. 2011, Ofuoku 2011, Legesse *et al*. 2013, Mdungela *et al*. 2017) that found farm size significantly influenced coping strategy adaptation, with lack of adequate land being a major barrier to climate change adaptation. According to McBride & Daberkow (2003) there may be a critical lower limit on farm size that prevents smaller farms from adopting climate change strategies, given the uncertainty and costs associated with innovation. Households owning smaller farms were less likely to innovate, because they were more risk averse. Opie (2011) observed land size to significantly affect asset-based strategy and mixed strategy coping mechanisms but not food-based strategy. Maddison (2006) and Hassan & Nhemachena (2008) concurred with this result, arguing that farmers with large land areas had more land to allocate to soil conservation and other strategies than those with small pieces of land.

The current study found households with larger farms were less vulnerable to drought. This is probably because they were likely to have more farm produce and more pasture and fodder for their livestock, in addition to having more land to diversify their farming activities. The households with larger farms were also likely to have higher yields in the more favourable years which could be stored and used during the lean years. The contradictory results observed in the current study were probably related to severe land degradation, which necessitates betters soil fertility management to obtain reasonable yields, even in good rainfall years. Hence farm size may make little difference to vulnerability, in the absence of adequate manure to fertilize the land or where land management practices are inappropriate.

Type of farming activity

The type of farming activity significantly affected the level of resilience, with livestock husbandry farmers and those who practised mixed farming being more resilient than crop farmers. Crop and livestock integration, diversification of livestock and crops, changing farming location and timing are some measures to be included in a repertoire of adaptation measures (IFAD 2010). The soils in the NCN are

heavily leached with low organic matter content (Keyler 1995, Prudat *et al.* 2018) and poor moisture retention contributing to poor crop yields. Livestock are more resilient as they can utilise poor quality forage and also mopane shrubs to survive. Thus crop-livestock farmers and those with livestock tend to fare better than those entirely dependent on crops during drought years. Hassan & Nhemachena (2008), in agreement with the current study, identified diversification into multiple crops and mixed crop-livestock system, switching from crops to livestock and switching from dryland to irrigation as possible ways of mitigating the effects of climate change in different parts of Africa.

Level of education

The results of this study show that education level does significantly affect household resilience to drought, that is, it does not affect households' ability to employ drought preparedness strategies. The current findings concur with other studies (John *et al*. 2011, Moyo *et al*. 2013, Mdungela *et al*. 2017) that observed the level of education to have no significant effects on households adopting drought coping mechanisms. Contrary to the current findings, other studies concluded that education increases households' chance to adapt as it increases households' understanding of climate change and awareness of different coping alternatives (Deressa *et al*. 2010, Ofuoku 2011, Nti 2012, Tazeze *et al*. 2012, Rakgase & Norris 2014, Alam 2015). Education level and receptivity to new innovations are just pieces of a puzzle; coping with the effects of drought and climate change in general also requires support systems by way of secure land tenure, infrastructural development (for example irrigation systems), access to credit, improved marketing, improved seed (e.g., drought tolerant varieties) and improved extension and veterinary services. However, education levels affected household vulnerability levels, implying that more educated household heads are less likely to employ coping mechanisms that make them more vulnerable to drought consequences. This is probably because those with a higher level of education were more likely to have other sources of income, allowing them to employ better drought mitigation strategies if a drought had already occurred.

Farming experience

Farming experience significantly affected household drought coping strategies with experienced farmers seemingly being more resilient. Experienced farmers were probably more knowledgeable about ways of mitigating drought and were more likely to adapt. In addition, they were more likely to use indigenous knowledge systems to better forecast weather than less experienced farmers. These results concur with the findings of John *et al*. (2011) and Mdungela *et al*. (2017) who concluded that farmers with experience were more likely to adopt drought coping mechanisms and hence reduce vulnerability to drought effects. Ofuoku (2011) observed that experienced households had a better understanding of climate change, while Hassan & Nhemachena (2008) also argued that the more experienced the farmers were, the more likely they were to adopt drought coping mechanisms. They propounded that experienced farmers had better knowledge and information on climate change and agronomic practices that they could use to cope with climate change. They may, for instance, store crop stover (residue) such as pearl millet and sorghum stalks, cow pea haulms; they may also have their animals distributed among distant relatives hence reducing livestock loss; they may also be able to better utilise encroacher bush species for animal feed.

Age of farmer

In this study, the age of the farmer was not significant in determining the household level of resilience and vulnerability to drought. Nevertheless, elderly farmers were more experienced in farming and had more indigenous and technical knowledge on drought preparedness and mitigation. They may also have better networks, which could serve as a social safety net in cases of drought. In addition, they were likely to be more experienced in forecasting upcoming droughts. The current findings do not agree with the studies of Ajao & Ogunniyi (2011), Opie (2011) and Tazeze *et al*. (2012) who found age to significantly affect household adaptation with older household heads having higher chances of adopting drought coping mechanisms. On the other hand, these results concur with the findings of Hassan & Nhemachena (2008), John *et al*. (2011) Moyo *et al*. (2013) and who observed the age of the household head not to be a significant factor in adopting coping mechanisms. Hassan & Nhemachena (2008) suggested that it is experience rather than age that matters for adaptation to climate change but failed to add that experience comes with age. However, the two are usually correlated and thus in the current study, their effects were similar.

Asset and livestock ownership

Asset ownership had a medium effect size on the drought adaptation for households. This agrees with Opie (2011) who observed the adoption of coping strategies to be associated with household assets such as land, livestock and other household assets; with farmers having more assets highly likely to adopt drought coping mechanisms. Deressa *et al.* (2010) and Tazeze *et al*. (2012) observed livestock ownership to significantly increase household probability to adapt. Legesse *et al.* (2013) also argued that herd size significantly affected coping strategy adoption, with households with larger herds more likely to adapt. Households with more assets are less vulnerable to consequences of drought probably because they have more resources with which to

handle drought. Wealthier families are also likely to take more risk and easily adopt new technologies and innovations (e.g., storage tanks for pearl millet, irrigation, urea-molasses blocks, planting of fruit trees, fencing off land), which may improve their resilience to drought. It could be argued that possession of more assets is a proxy for family wealth, implying that families with more assets would be in a better position to withstand the effects of drought and climate change in general.

Membership of farming organisations

Membership of a farming organisation improved household resilience to drought. This is probably because the households belonging to farming organisations were trained on drought adaptation and mitigation strategies, making them more prepared to deal with consequences of drought. They might also have better access to improved farming practices (e.g., use of molasses-urea blocks, early planting, manure application techniques, water harvesting techniques, forage production for livestock, improved animal health care) and better access to input supplies and markets. These findings were in agreement with those of Nti (2012) who reported that membership of farm organisations positively affected households' ability to adapt to the effects of drought.

Information dissemination, early warning signals and awareness

Farmers' awareness of the impending drought did not significantly affect household resilience and vulnerability to drought. This is probably because most households were aware of the forthcoming drought making the comparison between those who were knowledgeable and those with limited access to information difficult to assess. Moreover, it was not very clear from the data collected at what time the households became aware of the drought. The current results contradict the findings of Ndlovu (2009), Ofuoku (2011), Jordaan (2012) and Mdungela *et al.* (2017), who found that farmers who received information prior to drought had higher chances of adopting to drought coping strategies. However, studies in north-central regions of Namibia (Angula & Kaundjua 2016) have revealed poor warning systems for forecasting rainfall and temperature, limited access to information and eroded agroecological indigenous knowledge to be among the factors compounding households' vulnerability to drought and other climatic shocks. Notwithstanding access to information having non-significant effects in the current study, the African Adaptation Project (2010) advocated the need for early warning systems to enhance coping strategies with regards to potential disasters such as extreme drought. Kuvare *et al.* (2008) observed that early warning management systems were inadequate, leaving the government and communities ill-prepared to deal with large humanitarian emergencies.

Diversification of livelihood activities

Although the average resilience levels for households that owned a shop and those who planted fruit trees were still low, they were significantly higher than for those who relied on farming activities alone. These is probably because households that diversified their livelihood activities had alternative food, feed and income sources compared to those that did not and thus were less likely to deploy asset-depleting coping strategies. In addition, fruit trees were important for nutrition and contributed to food security during drought periods; they might also be a source of income for households with enough to sell and provide shade for humans and livestock during drought and hot seasons. In addition, some fruit trees such as guavas and mango trees are also good for carbon sequestration (Shinde *et al.* 2015), which reduces the amount of carbon dioxide in the atmosphere, thereby reducing global climate change. The low proportion of households that diversified their livelihood sources agrees with Angula & Kaundjua (2016) who identified the low capacity to diversify livelihood activities beyond subsistence agriculture as one of the barriers to climate change adaptation in north-central Namibia.

CONCLUSIONS

Membership of farming organisations reduced vulnerability levels probably because members were better informed and may have improved access to inputs and marketing opportunities. Hence formation of farmers' organisations should be encouraged. Evidence suggested a disparity in resilience and vulnerability based on the gender of the household head. This may call for gender mainstreaming in farmer training and support services, bearing in mind the differential access to resources and information. Households should be encouraged to diversify their farming activities, receive training in conservation agriculture and rehabilitate degraded rangelands. Households should be encouraged to leverage the available pool of labour to increase resilience through: diversification of livelihoods by engaging in other income earning activities; increasing crop diversity; planting of fruit trees; fodder production and conservation (hay, silage); and making better use of crop residues for livestock feeding, for instance by urea treatment. This is particularly pertinent to large households to reduce their vulnerability to drought effects. More farmer training and extension services are needed to improve households' capacity for drought adaptation and mitigation. Training should go hand-in-hand with improved infrastructure (e.g., for irrigation, food and feed storage), access to credit, improved markets, veterinary services, research support and policy reforms on secure land tenure. Households should be empowered through measures that enhance drought risk preparedness enabling them to better cope with climate change effects.

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Appendix 1: Structured questionnaire covering aspects of household socioeconomic and demographic characteristics, *ex-ante* adaptation coping strategies and *ex-post* maladaptation coping strategies employed to guard against the effects of drought by households in northern-central Namibia (n = 80).

My name is Dorthea K. Shiimi, a fourth-year student at the University of Namibia Department of Agricultural Economics. I am carrying out a survey for my research project in order to collect information on farmer's climate change adaptation and mitigation strategies, this questionnaire is sent to you for academic and scientific purposes. The information collected from you is highly privileged and will be kept confidential. You are free to withdraw from the interview at any time. Thanks in advance for your cooperation.

Interviewee Consent
Name of Interviewee: ..... **Date: .....** **District: .....** **Village name: .....** **Contact details: .....** **I..... (Surname & Initials) hereby acknowledge that I have read the interview's purpose and have given my consent to participate in it as a respondent.** **Signature**: .....

Section A: Household socio-demographic information

1. Age of respondent: .....

2. Gender of respondent

1. Male ☐ **2. Female** ☐

3. Marital status

1. Married ☐ 2. Single ☐ 3. Divorced ☐ 4. Widowed 5. Separated

4. What is the highest grade/education level achieved?

1.No Formal education ☐ 2. Primary ☐ 3. Secondary ☐ 4. Tertiary ☐

4b. Years of formal education..... (Years)

5. Household size.....

6. For how long have you been farming? ..... (years)

7. Type of farming activity

1.Livestock farming ☐ 2. Crop farming ☐ 3. Mixed farming ☐

8. Are you a member of any farmers' organization?

1. Yes ☐ **1. No** ☐

9.Do you own any livestock?

1. Yes ☐ **1. No** ☐

9a. If yes, how many of the following livestock do you own?

Type of livestock	Number owned
1.Cattle	
2.Goats	
3.Sheep	
4.Chicken	
5.Pigs	
6.Donkeys	
7.Other (specify)	

10.Do you own any household assets?

1. Yes ☐ **1. No** ☐

10a. If yes, how many of the following assets do you own?

Type of livestock	Number owned
1.Cars	
2.Wheelbarrows	
3.Cellphones	
4.Donkey carts	
5.Plough	
6.Cultivators	
7.Hoes	
8.Other (specify)	

Section B: Respondents' drought perception and awareness

1. What do you understand by drought?

……
……
……
……

2. Were you aware of impending drought incidence before its onset?

1. Yes ☐ **1. No** ☐

2a. If yes, through which medium did you receive the information from? Tick all that apply

Media	Tick
1. TV	
2. Radio	
3. Newspaper	
4. Farmer organisation	
5. Friends and neighbours	
6. Extension officers	
7. Other (specify)	

Section C: Effects and responses on the livestock herds

1.Do you own any livestock?

1. Yes ☐ **2. No** ☐

2. Did you experience any problems in availing water for your livestock during the drought?

1. Yes ☐ **3. No** ☐

2.a If yes, how were your livestock affected?

1. Not severe ☐ 2. Moderately severe ☐ 3. Very Severe ☐

3. How many water sources did you have access to for your livestock before the onset of the drought? ……..

4. What type of water sources were they and what were the distances to these sources? (provide distance to the water source in km)

Type of water source	Before drought	During drought
1. Stream		
2. Borehole		
3. Digging in stream beds		
4. Ponds		
5. Concrete in ground		
6. Concrete above ground		
7. Reservoir/dam		
8. Others*		

*Specify

5. How many grazing sites do you have access to? .....

6. What was the distance to the primary grazing sites? …… (km)

7. Did you experience any problems in availing feed/pasture for your livestock during the drought?

1. Yes ☐ **2. No** ☐

7a If yes, how were your livestock affected?

1. Not severe ☐ 2.Moderately severe ☐ 3.Very Severe ☐

8. What was the most significant livestock management change you experienced during droughts?

……
……
……
……

9. Did you fence to protect the water source?

1. Yes ☐ **1. No** ☐

10. Did you fence to protect the grazing areas for your livestock?

1. Yes ☐ **1. No** ☐

11. Did you prepare for feed for your animals before the onset of the drought?

1. Yes ☐ **1. No** ☐

11a If yes, what form of preparation did you make (tick all that apply)

Preparation made	Tick
1. Preserved pearl millet stalks for animals	
2. Preserve uncultivated land for animals	
3. Other (specify)	

12. Did you move your livestock to areas with better grazing pasture (eg cattle posts)?

1. Yes ☐ **1. No** ☐

Section D: Effect and response on crops

1. Do you practice crop farming?

1. Yes ☐ **1. No** ☐

1a. If yes, what area of land do you cultivate during normal seasons and drought periods?

Period	Land area (Ha)
Normal period	
Drought period	

2. To what extent did the drought affect your crops?

1. Not affected ☐ 2. Not severe ☐ 3. Moderately severe ☐ 4. Very Severe ☐

3. At what growth stage did you lose your crops because of the drought?

1. Germination ☐ 2. Vegetation ☐ 3.Reproduction stage ☐ 4. Seed formation ☐

4. How was your crop yield affected?

1. Not severe ☐ 2. Moderately severe ☐ 3. Very Severe ☐

5. Did you have to change your cropping system during the drought period?

1. Yes ☐ **1. No** ☐

5a. If yes, what type of cropping system did you employ during the drought period? Tick all that apply.

Cropping system	Tick
1. Intercropping	
2. Wide spacing	
3. Shifting to quick maturing crops	
4. Planting drought-resistant varieties	
5. Cultivation of vast areas in different directions	
6. Crop rotation	
7. Conservation agriculture	
8. Other (specify)	

6. Did you plant drought-resistant varieties/crops?

1. Yes ☐ **1. No** ☐

6a. If yes, which drought-resistant crops/ varieties did you grow?

……
……
……

7. Did you irrigate crops during the drought

1. Yes ☐ **1. No** ☐

7a. If yes, which irrigation system did you employ?

1. Mini irrigation system ☐ 2. Hand irrigation ☐

Section E: Farmers' Strategies in response to consequences during drought

1. Did of preparation for the welfare of your household before the onset of the drought?

1. Yes ☐ **1. No** ☐

1a. If yes, what kind of preparation did you put in place? (Tick all that apply)

Preparation strategy	Tick
1. Save pension money to buy food	
2. Own a small shop to earn money	
3. Plant fruit trees	
4. Borrow money to stock food	

2. Did you draw upon stored foods during a drought?

1. Yes ☐ **1. No** ☐

4. Did you seek wild fruits or hunt animals as a result of food shortage during drought?
1. Yes ☐ **1. No** ☐

5. Did you render services or assistance in exchange for food during these periods?
1. Yes ☐ **1. No** ☐

6. Did you have to disperse family members during any phase of drought in order to meet family needs?
1. Yes ☐ **1. No** ☐

7. Were you forced to seek employment elsewhere during the drought period?
1. Yes ☐ **1. No** ☐

7.1 If yes, did you get employment within your locality or you had to migrate?
1. Within locality ☐ **2. Migrate** ☐

8. Did you have to borrow food or rely on help from friends and relatives at some point during the drought?
9. Did you sell or pledge any productive assets in order to buy food during a drought?
1. Yes ☐ **1. No** ☐

10.1 If yes, what type of assets did you sell……..
11. Was selling your assets able to achieve the aim of sale?
1. Yes ☐ **1. No** ☐

11a. If not, what was the reason why not?
……
……
……
……
12. Can you conclude that the coping mechanisms you adopted helped to ease the effect of drought on your household?
1. Yes ☐ **1. No** ☐

12a. Why or why not?
……..……...…
….....……..……..…..…
……..…….....…….....
.....

Section F: Section for village-level coping strategies

1. Are there any village forest reservation strategies or laws in place that prohibit farmers from cutting down trees?
1. Yes ☐ **1. No** ☐

2. Are there any village soil conservation techniques in place?
1. Yes ☐ **1. No** ☐

3. Are there any of the following community projects in the area?
3.1 Community dam?
1. Yes ☐ **1. No** ☐

3.2 Fish farming project?
1. Yes ☐ **1. No** ☐

3.3 Irrigation project in the area?
1. Yes ☐ **1. No** ☐

Appendix 2: Parameter estimates for the general linear model on factors affecting household drought resilience of households in northern-central Namibia (n = 80).

Parameter*	B	Standard error	Lower bound	Upper bound
[Gender = Male]	0.558	0.299	-0.039	1.156
[Gender = Female]	0			
[Marital status = Married]	0.337	0.310	-0.017	0.583
[Marital status = Single]	0			
[Farm organisation* = No]	-2.482	0.705	-3.889	-1.074
[Farm organisation = Yes]	0			
[Farm activities = Livestock]	1.770	0.932	-0.091	3.631
[Farm activities = Crop]	-0.335	0.387	-1.107	0.437
[Farm activities = Mixed]	0			
Household size	0.060	0.045	-0.030	0.150
Years of farming experience	0.016	0.013	-0.009	0.041

**Farm organisation refers to whether household had membership to a farming organisation or not. Farm activities refers to the type of farming activities in which the household was engaged.*

Appendix 3: Parameters from the general linear model of factors affecting household vulnerability to drought for households in northern-central Namibia (n = 80).

Parameter*	B	Standard error	Lower bound	Upper bound
[Farm organisation* = No]	1.099	0.902	-0.703	2.900
[Farm organisation = Yes]	0			
[Farm activities = Livestock]	-1.663	1.193	-4.044	0.719
[Farm activities = Crop]	-0.324	0.495	-1.312	0.664
[Farm activities = Mixed]	0			
Household size	0.117	0.058	0.002	0.233
Years of farming experience	-0.029	0.016	-0.061	0.004
Asset index	-0.442	0.183	-0.807	-0.078
Livestock index	0.042	0.248	-0.454	0.538
Years of education	-0.040	0.065	-0.169	0.089

**Farm organisation refers to whether household had membership to a farming organisation or not. Farm activities refers to the type of farming activities in which the household was engaged.*